2015

The Amazing Maze

ME-498 TOY DESIGN, SPRING 2015

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Contents

Project: The Amazing Maze

Problem Definition

Information was gathered through interviewing the teachers and children (ages 4-8) at the Milwaukee Center for Independence's School for Early Development and Achievement (SEDA). The specific needs of the children, identified by the teachers [1], were spatial reasoning and sensory stimulation. From that information, it was determined that there is a need for an interactive toy that further develops students' motor skills, creativity, and problem solving skills, while providing them positive sensory feedback. The need for motor skill development and creativity was confirmed by the kids who liked building things and working with numbers/shapes.

Objectives

The following objectives were established in order to provide a clear basis for identifying and defining design options, as well as outline characteristics of the toy that need to be optimized in order to solve the problem:

1. Safe for typically developing children age 6+ and children with Autism Spectrum Disorder (ASD).
2. Durable: Difficult for the child to disassemble or break through force.
3. Develops the child's problem solving skills.
4. Fun and rewarding (a sense of achievement) for the child.
5. Intuitive: Low learning curve on how the child should interact with the toy.
6. Develops the child's fine and gross motor skills.
7. Captures and holds the child's attention.

Constraints

Proposed toy designs must adhere to the following mandates in order to be considered:

1. Compliance with ASTM F963 Safety Standards.
2. Safety
    a. Smooth/Dull edges and surfaces.
    b. Loose pieces must be too large to swallow.
    c. Throwing hazards
        i. Large, loose objects must be too heavy to be thrown by child.
        ii. Small, loose objects must be light enough to not cause harm.
3. Able to be moved by an adult in accordance with OSHA ergonomic standards [3].
4. Competitive with cost of comparable toys.

Design Specifications

The following are desired design features and characteristics of the final design:

1. The maze will have a footprint whose dimension is between 1 and 9 square feet.
2. Height between 3 inches and 9 inches.
3. Weight between four and nine pounds.
4. As a main goal, children will move a small ball (⅛" to ½" diameter) from a predetermined start location to a final destination.
5. A guard will keep the ball enclosed at all times.
6. All electronic components will be safely enclosed and secured.

7. Batteries will be able to be replaced relatively easily by an adult.
8. Upon reaching the final destination, lights and/or buzzers will be activated to give children a sense of achievement and accomplishment.
9. A timer will provide constant visual stimulation to the children.
10. Have an on and off switch.
11. Cost of $75 - $100 to manufacture (up to $200 for prototype).
12. Provide more sensory feedback than similar toys.

Weighting Criteria

Listed below are the toy design weighting criteria and definitions:

- Simplicity of movement mechanism 15%
- Cost 10%
- Weight 5%
- Aesthetics/Appeal 15%
- Ease of use 20%
- Durability 15%
- Sensory feedback 20%

Simplicity of movement mechanism – The simplicity/complexity of the mechanism for moving the ball around the game board. Simple is better.

Cost – The estimated manufacturing cost of the final design. The estimate is based on the cost of the components required to produce the toy prototype. Inexpensive is better.

Weight – The overall weight of the toy. The toy must be light enough for an adult to move safely, but heavy/awkward enough to prevent a child from picking it up and throwing it. Closer to 8lbs is better.

Aesthetics/Appeal – The visual attractiveness that draws children to play with a toy. Brighter and a larger variety of colors is better.

Ease of use – How intuitive/natural a child interacts with the toy. A toy that is easier to understand and learn how to play with is better.

Durability – The degree to which a toy handles the normal abuse that is delivered by a typical child that is 6+ years-old. More durable is better.

Sensory feedback – The methods in which the toy stimulates the child in a positive manner. The types of sensory stimulation are touch, sight, sound, smell, and taste. More types of sensory stimulation is better.

Design of The Amazing Maze

Mechanical Design Description

There are three main components to the mechanical design, in addition to the maze housing:

1. Ball Manipulation
2. Ball Return System
3. Battery Compartment

The maze will be completely enclosed by an ABS plastic housing in order to deny children access to small pieces. The maze will have a transparent ABS cover to allow for viewing of the game. The plastic will be 3/16" and includes hollow features wherever possible to reduce weight and material usage.

Figure 1 shows the ball manipulation system that features a central pivot joint, four springs, and four corner spring compressors.

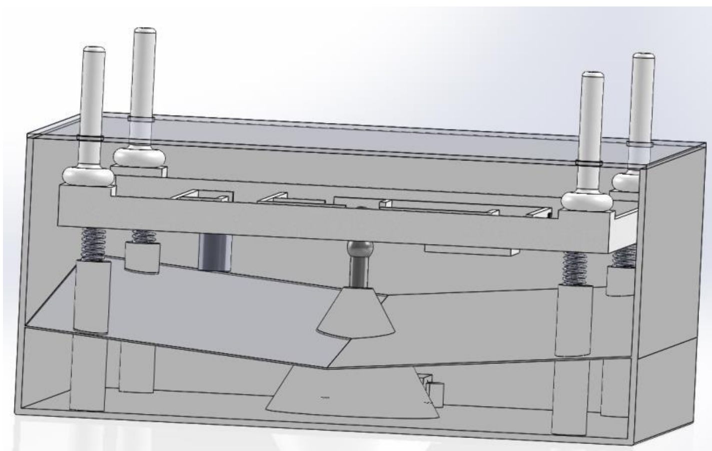


Figure 1. Sectional view of Ball Manipulation System

The central pivot gives the maze board freedom to tilt in any direction needed to get the ball moving. The springs (spring constant of 10 lb/in.) in each of the four corners force the board into a horizontal equilibrium position. Force can be applied to any of the four corner spring compressors, causing the board to tilt in the direction of the corner spring compressor. The corner spring compressors must be strategically pressed to tilt the board in a direction which will cause the ball to move toward the goal.

As seen in Figure 1, the floor is slanted; this forces the ball to return (after falling through the board) to a central exit hole on the side of the housing. The ball drops into a channel with an elevator at the bottom. The ball will be pushed up the channel and drop into a re-entry tube, seen in Figure 2.

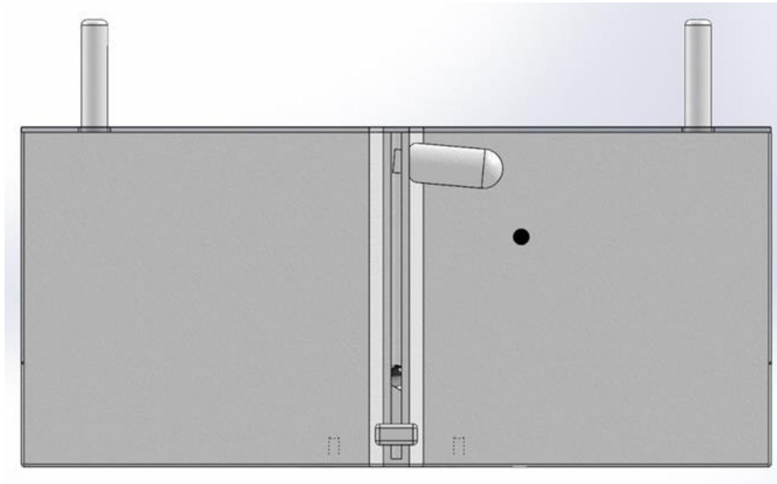


Figure 2. Ball Return Mechanism

The design also features a battery compartment; this holds four AA batteries used to power the electrical system of the toy. Figure 3 shows the compartment cover, which allows the batteries to be replaced by removing the two screws with a Phillips screwdriver.

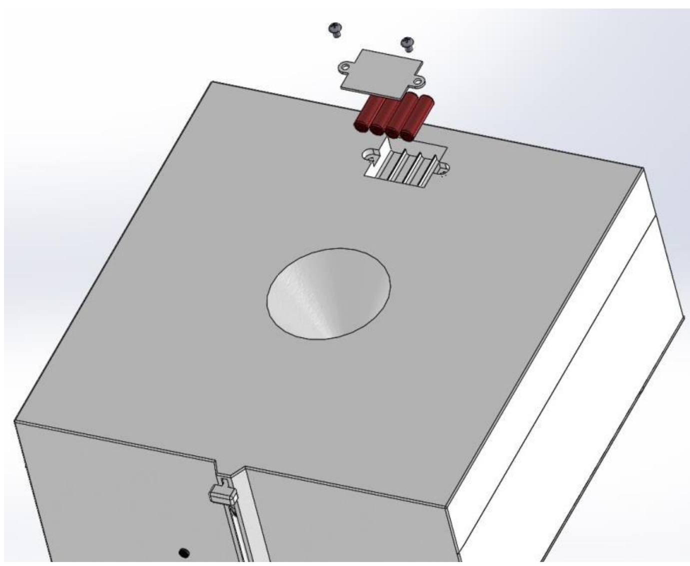


Figure 3. Battery Compartment

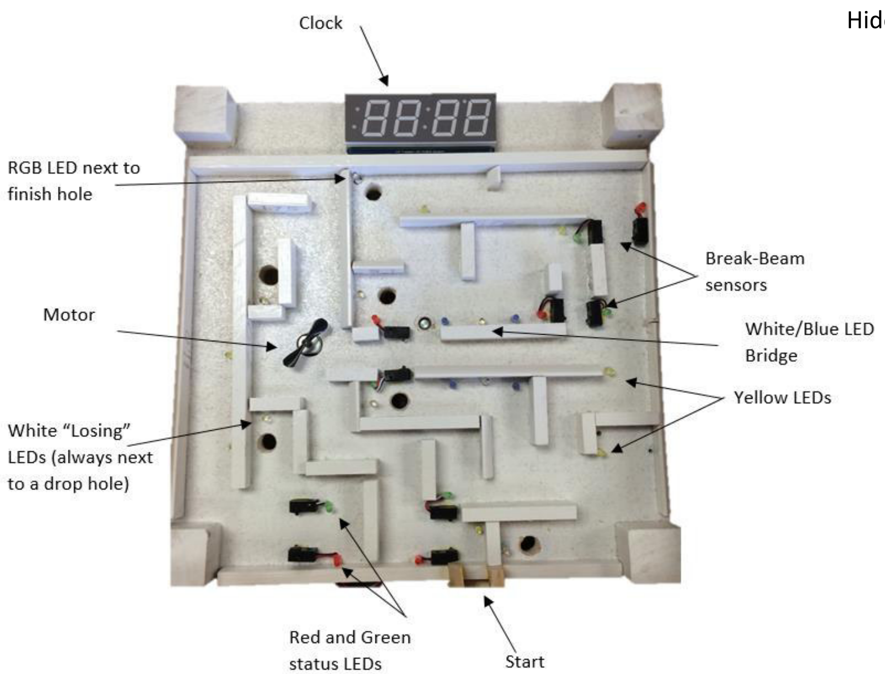
Electrical Design and Gameplay Description

As one of the main goals of this project was to help develop the sensory skills of a child with ASD, an electrical system was designed to provide audio and visual feedback to stimulate these senses. Table 1 depicts the sensors chosen and the purpose they played in the game.

Table 1. Sensor Purpose

	Sense being stimulated	Game Purpose
Break-Beam	Visual	Checkpoints to pass the marble through. Each passed checkpoint is worth 1 point
Red/Green LEDs	Visual	Checkpoint Status: Red means "not passed"; Green means "passed"
Yellow LEDs	Visual	Blink when checkpoint is passed (provides a sense of reward)
Blue and White LEDs	Visual	Displays a Light Show whenever a specific checkpoint is passed
Buzzer	Audio	Play a Win, Lose, or checkpoint passed "song" accordingly
RGB/White LEDs	Visual	RGB LED changes color throughout game play and blinks multiple colors if the game is won. White LEDs blink if game is lost
Motor	Visual	Provides a moving obstacle (makes the game more exciting and replayable)
Clock	Visual	Tracks time and blinks score everytime a checkpoint's status changes

These sensors were then mounted on the game board as shown in Figure 4.



Hidden:

- Break-Beam sensor underneath winning hole and right behind the drop-zone hole at the base of the board
- Buzzer mounted underneath the board

- Electronics are mounted on the reverse side of the game board

Figure 4. Game Board Layout

At start up, the clock will be blink 00:00 and the red status LEDs will illuminate. Once, the checkpoint at the start position is passed, the clock will begin to count and the motor will be activated to run on a specific time schedule (5 seconds on and 5 seconds off). In a typical game, the child will start at the start position, and work their way through the game-board by using the corner spring compressors (not shown in Figure 4) at each corner. Each time the ball goes through a checkpoint for the first time, the status LEDs will switch from red to green, the yellow LEDs around the board will blink, the clock will blink the total accumulated score, and the buzzer will chime a short song. The clock will then resume displaying the time since the game started and the motor will continue on its spinning schedule. If the ball goes through the central checkpoint again after its first initial pass, the white and blue LEDs next to the checkpoint will display a short lightshow to provide some additional feedback. If the ball falls through the winning hole, the RGB LED will flash different colors, the clock will blink the total score, the buzzer will play a "winning" song, the clock will blink the total elapsed time, and each LED will sequentially light up and turn back off. Likewise, if the ball falls through any of the other holes, it will break the beam of the hidden sensor near the base of the board and cause the white LEDs to flash, the clock will blink the total score, the buzzer will play the "losing" song, and then the clock will display the total elapsed time. The maze would then reset itself for a new game. A more detailed flowchart depicting the sequence of events can be found in Figure 5 on pages 10 and 11.

These sensors (in the prototype) were controlled via an Arduino microcontroller and were hooked up according to Figure 6 on page 12. The main differences between the prototype and final design are shown in Table 2.

Table 2. Prototype vs Final Design

Prototype	Replaced with	Final Design
Arduino Uno	→	Arduino IC components
BreadBoard	→	Custom PCB
LED Driver	→	TLC5497 IC
Two 9v in parallel	→	Four AA batteries
Tons of Wires	→	Minimal Wire Amount
H-Bridge		H-Bridge
Motor		Motor
Buzzer		Buzzer
26 LEDs		26 LEDS
Clock		Clock
Toggle Switch		Toggle Switch

All of the electronics will be soldered onto the custom printed circuit board (PCB), which will be the same size as the actual game board and weigh approximately 1 lb. The PCB will then be inserted flush underneath the game board (via screws) which would have all of the necessary holes for the sensors pre-molded.

Finally, four AA batteries were selected to run the system because four AA batteries provide more current than two 9v batteries (i.e. have higher capacity), and are more inexpensive. This matters since the motor tends to draw a lot of current and these batteries can provide that current without too much power being wasted over the 5v regulator. The decrease in wasted power means that AA batteries will last for a longer duration of time than the 9v batteries. As a separate note, batteries were chosen in general since it allows the toy to be portable, eliminating the tripping hazard that comes with plugging a cord into a power outlet. The elimination of the tripping hazard is important for all children, especially those with ASD.

Designing with ASD in mind

The design of The Amazing Maze was largely driven by the specific needs of a child with Autism Spectrum Disorder. Ms. Ciurro mentioned that multimodal stimulation is an important trait for a toy that is designed to be friendly to children with ASD [1]. The act of controlling the ball via the corner spring compressors provides direct physical feedback to the child's actions, while also providing visual stimuli (the ball and illuminated LEDs) to focus upon. The audio provided by the ball bouncing around the maze and activating the sound buzzer through the checkpoints completes the multimodal stimulation experience.

Children with ASD tend to avoid social interactions because they typically maintain poor eye contact and have difficulties processing social subtleties [1]. Ms. Ciurro also mentioned that the children possess underdeveloped motor skills [1]. Designing The Amazing Maze with four corner spring compressors encourages cooperative play and communication amongst the children, but does not require it. Although not included in the objectives of the final design, it is important to note that the option to play as an individual increases the likelihood that a child with a communication disorder, like Speech Sound Disorder, Language Disorder, or Child-Onset Fluency Disorder, will be interested in playing with The Amazing Maze. In the case that the child plays alone, although social interaction decreases, the concentration on developing gross and fine motor skills increases. With their two hands, the child will control all four corner spring compressors and be required to move around The Amazing Maze accordingly. The child will subconsciously work on gross and fine motor skills as they position their body around The Amazing Maze to apply the appropriate force to the corner spring compressor.

Final Design Assembly Drawing

See MAZE1 in Appendix A for the Final Design Assembly Drawing generated by SolidWorks.

Exploded Assembly Drawing and Bill of Materials

See MAZE1-EXPLODED in Appendix A for the Exploded Assembly Drawing generated by SolidWorks.

Bill of Materials

The components necessary to produce the final toy design are included in Table 3:

Table 3. Bill of Materials

Component	Cost	Price Reference
7.3 lb ABS Plastic Maze ($3/lb)	$ 27.38	[4]
Ball and Socket Joint	$ 3.65	[5]
Screws and Springs	$ 3.00	[5]
Integrated Circuit LED Driver	$ 3.81	[6]
Toggle Switch	$ 2.48	[6]
Clock	$ 1.00	[6]
Motor	$ 2.67	[6]
LEDs	$ 5.00	[6]
Arduino Integrated Circuit Components	$ 9.36	[6]
Printed Circuit Board	$ 10.00	[6]
Battery Holder	$ 3.67	[6]
Buzzer	$ 0.50	[6]
Component Total Cost:	**$ 72.52**	

Designed Parts

The parts designed by The Amazing Maze team are detailed in Appendix A.

- Maze Housing [MAZE1-1]
- Battery Cover [MAZE1-2]
- Maze Board with Integrated Circuit Board [MAZE1-3]
- Ball Return Pusher [MAZE1-4]
- Spinning Obstacle Wheel [MAZE1-5]
- Clear Maze Cover [MAZE1-6]
- Corner Spring Compressor [MAZE1-7]

System Software Flowchart and Diagram

Figure 5 illustrates how the maze's software functions and Figure 6 demonstrates the electronic wiring:

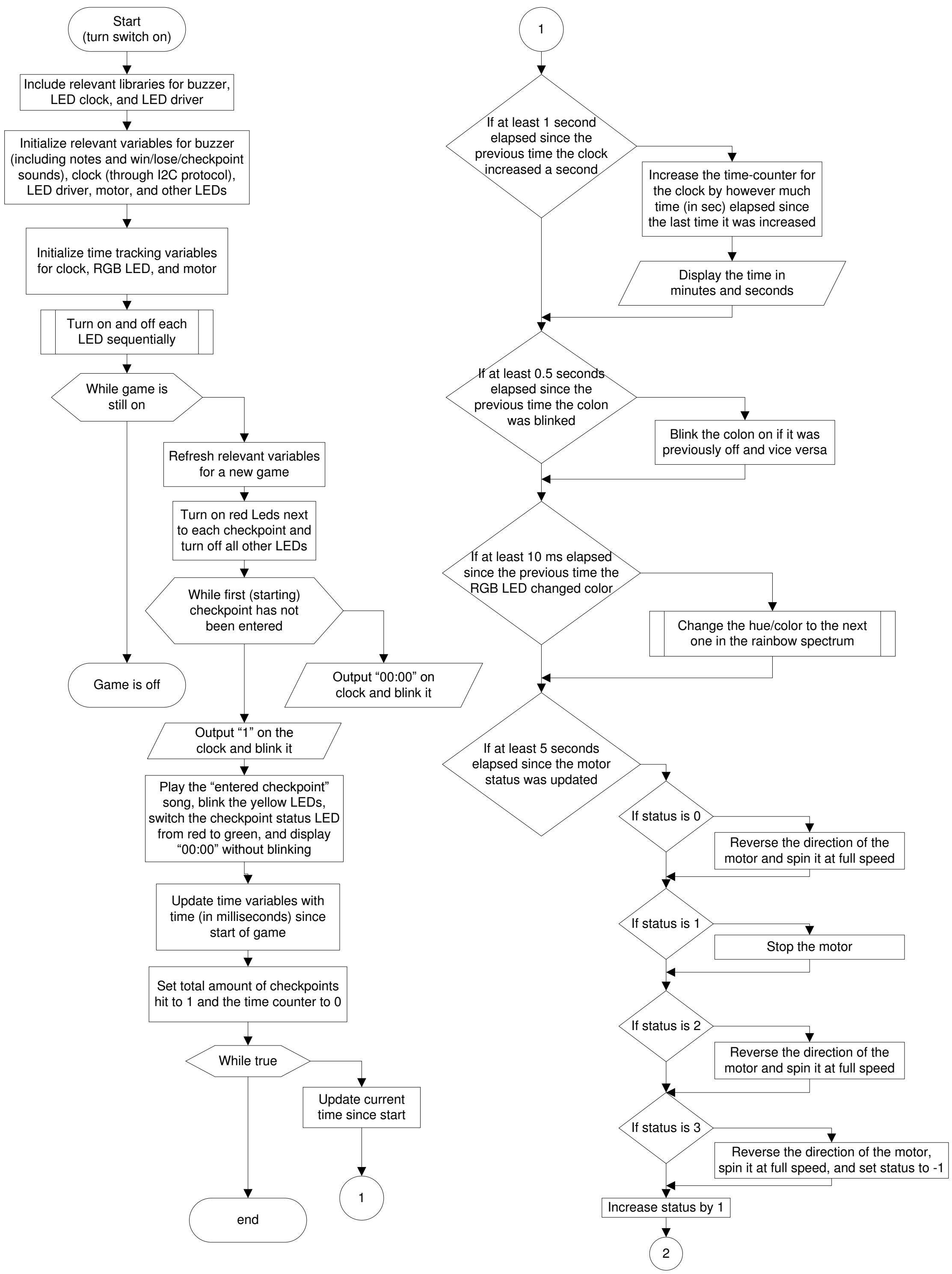


Figure 5. The Amazing Maze software flowchart

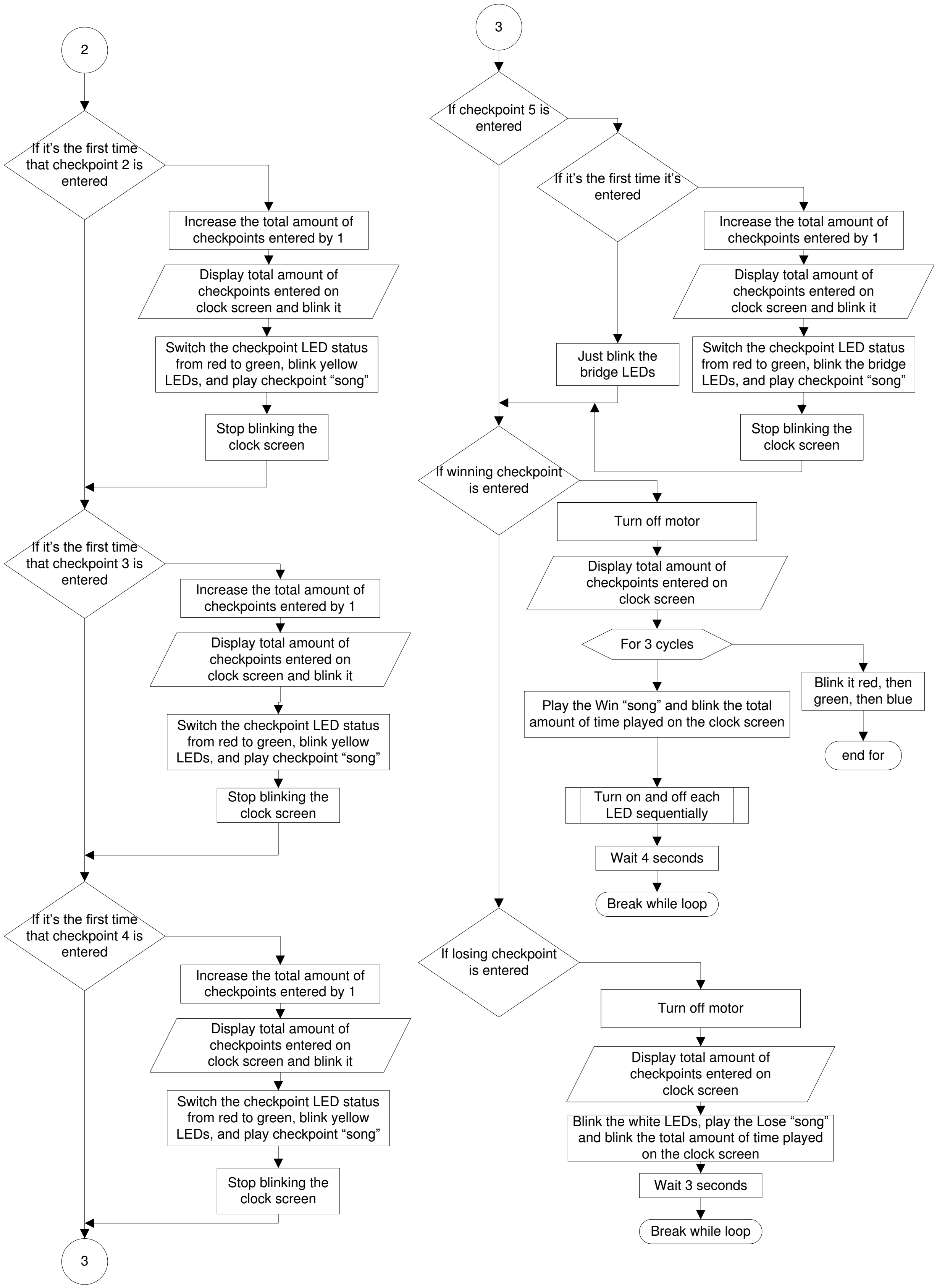


Figure 5 (cont.).The Amazing Maze software flowchart

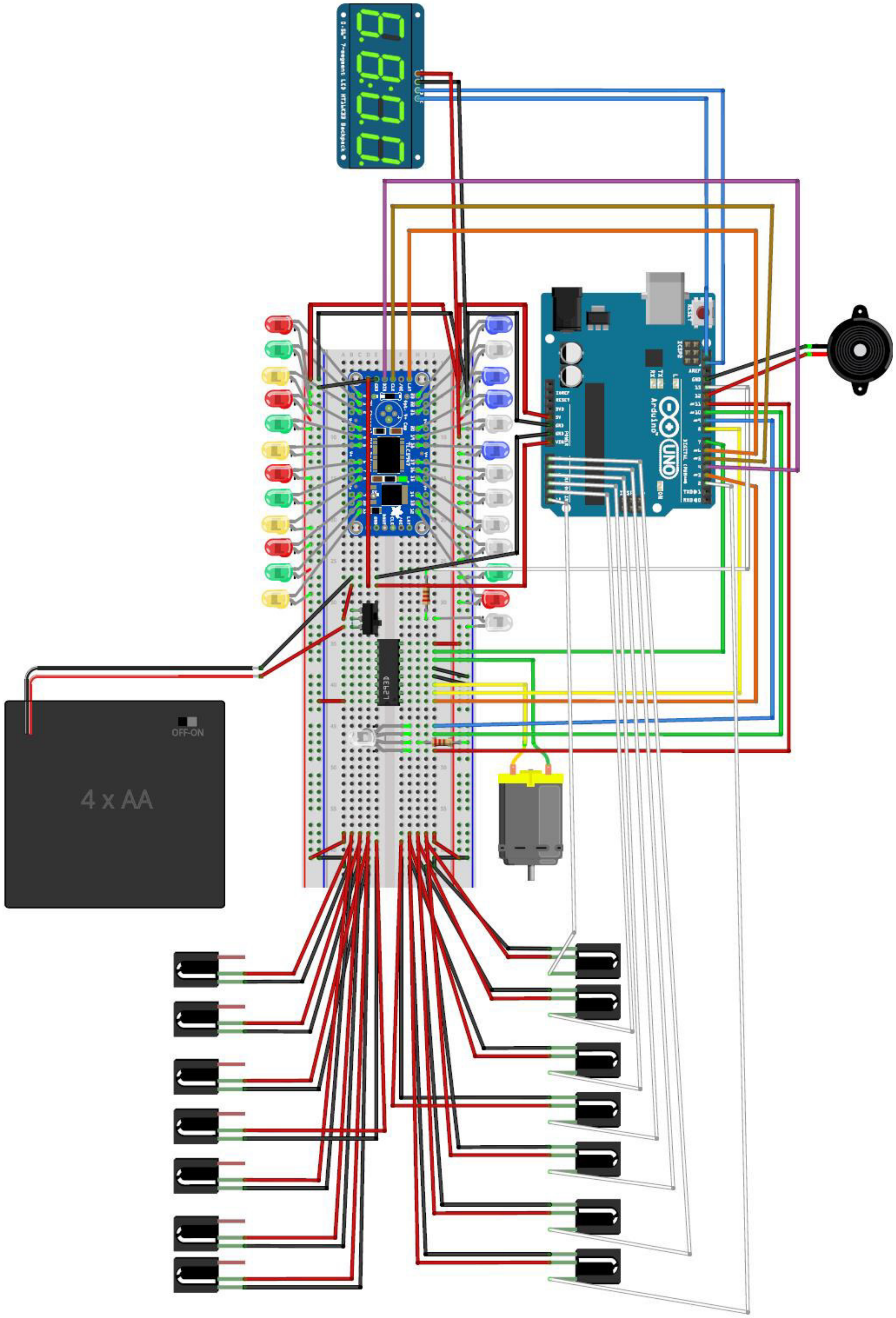


Figure 6. Electronic Wiring Diagram

Insert Table 4. Decision Matrix (Printed on large paper)

Design Analysis

Table 5 verifies that the final design meets all of the design specifications.

Table 5. Design Specification Checklist

Design Specifications	Final Design Spec.	Satisfy Spec.
Footprint between 1-9 ft^2	18 inches X 18 inches = 2.25 ft^2	y
Height between 3-9 in.	8 inches tall	y
Weight between 4-9lb.	7.3 lb. (Mechanical) + 1 lb. (Electrical) ≈ 8.3 lb.	y
Cost $75-$100 to manufacture	Manufacturing costs ≤ 1/2 Prototype costs ($160)	y
Keep ball enclosed	ABS maze cover, ball retrieval mechanism	y
Enclose all electronics	No exposed electronics	y
Have an on/off switch	Positioned next to ball retrieval mechanism	y
Easy battery replacement for an adult	Screwdriver required	y
Move ball from a start point to a finish point	Yes	y
Activate lights/buzzers upon completion of maze	Yes	y
Provide visual stimulation with a timer	Yes	y
Provide more sensory feedback than similar toys	20+ LEDs, sound buzzer, 7-segment time display	y

The drawing MAZE1-1 in Appendix A verifies that the footprint of the maze is between 1 and 9 ft^2.

The drawing MAZE1-1 in Appendix A verifies that the height of the maze is between 3 and 9 inches.

The drawing MAZE1 in Appendix A verifies that the weight of the maze is between 4 and 9 lb.

Table 3 on page 9 verifies that the cost to manufacture is between $75 and $100.

Figure 3 on page 5 verifies that the batteries are easily accessed and changed.

Table 6 verifies that the sensory feedback of The Amazing Maze is superior to that of comparable toys. To develop the list of competitor's games, a search was conducted on Amazon.com [2] for "maze games" and "electronic mazes."

Table 6. Sensory Feedback Comparison

	Methods of Feedback				
Game Name	Visual	Tactile	Auditory	Acknowledgement of "winning"	Total
The Amazing Maze	y	y	y	y	4
Gravity Maze	y	y	n	n	2
Perplexus Maze Game	y	y	n	n	2
MindWare Q-Ba-Maze	y	y	n	n	2
BRIO Labyrinth	n	y	n	n	1
Galt Toys Marble Run	y	y	n	n	2
Anatex Classic Bead Maze	y	y	n	n	2

Prototype Testing

The tests in this section were carried out in order to collect information and observations that could be used towards optimizing The Amazing Maze.

Spring Prototype Test

The objective of this test was to find the approximate spring constant of The Amazing Maze prototype's springs and determine if the springs for the final design should have a higher or lower spring constant.

We used the calipers and the Hanson (Model 895) hanging spring scale to measure the uncompressed lengths of the springs and the weight of the sprocket, respectively. Table 7 shows the recorded measurements, while Figures 7 and 8 show the methods of measurement:

Table 7. Spring and sprocket measurements

Spring uncompressed length	1.615 in.
Sprocket weight	3 lb.

Figure 7. Measuring the spring length

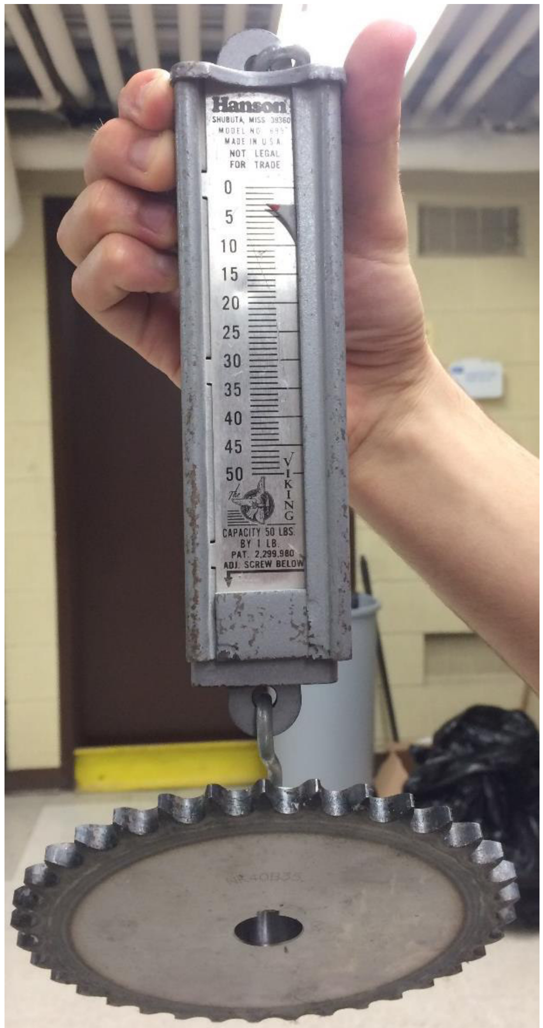


Figure 8. Measuring the sprocket weight

Hooke's law states that the force, *F*, required to compress a spring by some displacement, δ (also referred to as deformation), is proportional to the displacement. That is:

$$F = -k\delta$$

With *k* being the spring constant. This principle of physics holds true as long as the force stays within the spring's linear range (i.e. the spring does not stretch/compress to the point at which it permanently deforms).

Spring deformation is the difference between the uncompressed spring length and the compressed spring length:

$$\delta = compressed\ length - original\ length \qquad \text{(Eq. 1)}$$

The spring deformation being negative confirms that the spring has been compressed.

Rearranging Hooke's law and solving for the spring constant results in:

$$k = -\frac{F}{\delta} \qquad \text{(Eq. 2)}$$

The force of the sprocket was distributed over the four springs, in order to achieve a stable test apparatus. Modifying Equation 2 to take into account the additional springs results in:

$$k = -\frac{F}{4\delta} \qquad \text{(Eq. 3)}$$

The average displacement was for 3lb. on 4 springs was measured and averaged, shown in Figures 9 and 10, and Table 8.

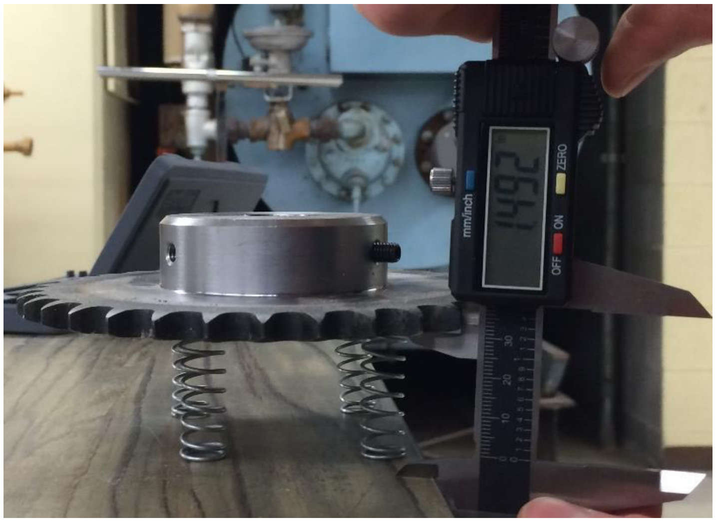


Figure 9. Left side spring deformation

Figure 10. Right side spring deformation

Table 8. Spring deformations

	Deformation distance (δ) [in]
Left side spring	-0.123
Right side spring	-0.033
Average	**-0.078**

Calculations were as follows:

Equation 1: $Deformation\ distance\ (\delta) = original\ length - compressed\ length$

Example: $\delta = 1.615in - 1.492in = 0.123in$

Equation 3: $spring\ constant\ (k) = -\frac{F}{4\delta}$

Example: $k = -\frac{3lb}{(4\ springs)(-0.078in)} = 9.62lb/in$

Using Eq. 3 to solve for the approximate spring constant, *k*, results in the approximate spring constant for the prototype being 9.62lb/in. This approximation is appropriate for a spring that was found in a non-industrial setting.

Based on how the children interacted with The Amazing Maze at SEDA, it was decided to specify springs with spring constant 10lb/in for the final design. These springs were deemed optimal because the existing springs, which are approximately 10lb/in., managed to provide a quick restoring force to the game board while the children played with the maze at SEDA, while maintaining physical integrity and showing no signs of plastic deformation. After surviving (in regards to the springs) the visit to SEDA and the borderline violent session of play with the 5-year-old children, The Amazing Maze's gameplay in no way suggested that the springs had been compromised.

MSOE Prototype Gameplay Testing Sessions

Through impromptu testing sessions with students and faculty at Milwaukee School of Engineering (MSOE), a couple aspects of The Amazing Maze's gameplay were optimized. The two gameplay aspects that received critique and optimizing were:

- Maze software
- Game board layout

The large number of trial games played on The Amazing Maze prototype aided in identifying and eliminating small loopholes in the software. Through the findings of the prototype testers, the software was optimized by increasing the time delays in the fan feature of the game board, in other words, decreased the duration that the fan ran and increased the duration that it remained stationary.

Other comments and suggestions from the prototype testers helped optimize the game board layout for the ease and intuitive use for children 6+ years of age. The finish line was made more obvious for younger children by incorporating the image of a checkered flag surrounding the hole. The checkpoints were made more obvious to older children by incorporating a numbering system that suggested an order in which the checkpoints should be passed through. The most substantial gameplay adjustment was the increased frequency at which the game provided visual and auditory feedback to the children, and the decreased duration of the feedback.

SEDA Prototype Test Session

The final test session that The Amazing Maze prototype underwent was held at SEDA with the K5 class. The children were of the ages 5-6 and they tested The Amazing Maze prototype to its full capacity. Approximately 15 children wanted to play with the maze at once, as shown in Figures 11 and 12.

Figure 11. Explaining the game to the children and teachers of SEDA

Figure 12. Children at SEDA playing with The Amazing Maze

The Amazing Maze lasted approximately 30 minutes before the protective Plexiglas covering was compromised, as shown in Figure 13. The compromise was caused by an unanticipated amount of force applied by the combined effort of multiple children on the single wooden corner spring compressor.

Figure 13. Compromised Plexiglas cover

The teachers and students at SEDA provided excellent feedback. Features that were praised were:

- The LED lights and colors
- The ability to move and control the game board
- The unpredictability of the fan
- The marble
- The action of pressing on the wooden corner spring compressor

When asked about what could be changed for The Amazing Maze final design, the teachers responded with the following comments:

- The maze needs to be more durable
- The maze may be better for an older audience
- The maze is difficult to play with so many children
- The timing of when the fan turned on was too frequent

The feedback of the children and teachers at SEDA provided will be incorporated in the final design of The Amazing Maze in the following ways:

1. The specified ABS plastic maze covering will be thicker (3/16 in.) and more robust than the 1/8 inch Plexiglas used on the prototype. In addition, the clearance between the ABS plastic maze cover and the corner spring compressor will be tighter than the clearance between the Plexiglas and the wooden corner spring compressor on the prototype. The tighter clearance will limit the corner spring compressor's ability to be pressed in a manner that is not vertical, reducing the amount of force that is applied in a manner that will pry the compressor out of the maze cover.

2. The age range of the toy will be increased from 4-8 to 6+. That will allow The Amazing Maze game board to remain in its current layout. An alternative way to address The Amazing Maze currently not being appropriate for 4 and 5 year old children is to greatly simplify the game board layout by increasing the pathway width and reducing the number of pathways.

3. The Amazing Maze's gameplay has been optimized with for a single user, or two users who communicate and cooperate when playing the game. The final design of The Amazing Maze will specify that the game is intended for 1-2 players at a time, which will enhance the children's ability to play and enjoy The Amazing Maze experience, while decreasing the likelihood of excessive force being applied to the game.

4. The frequency at which the fan turns on can be decreased in the software. Additionally, with fewer children attempting to control the ball with the corner spring compressors, the overall coordination and control of the ball will be improved. The improvement of the ball control will increase the likelihood of the center fan feature being navigated successfully.

Significant differences between the prototype and the final design

The following is a summary of the differences between The Amazing Maze prototype (Figure 14) and the final design (Figure 15).

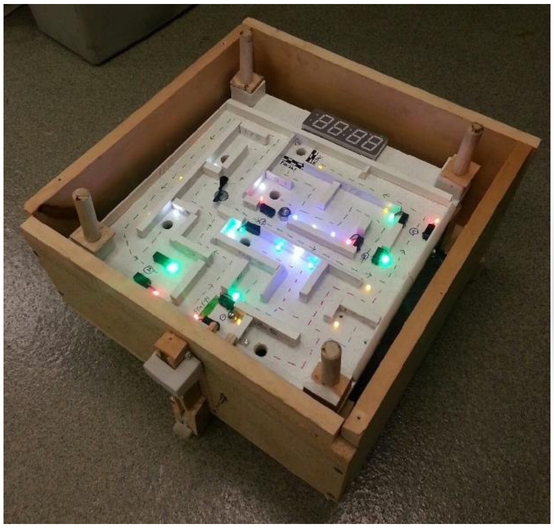


Figure 14. Prototype

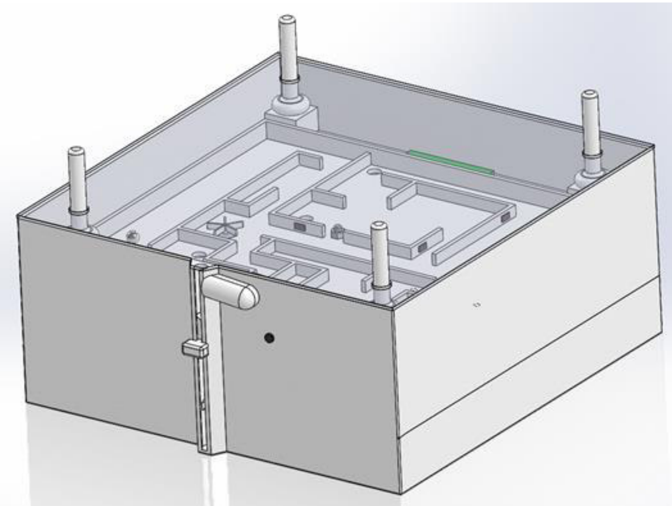


Figure 15. Final Design

In terms of the mechanical system of The Amazing Maze, the final design will have the following changes:

- The final design is made completely out of ABS plastic, including the maze cover, rather than the wood and Plexiglas used for the prototype.
- The corner spring compressors will be made out of ABS plastic, rather than wooden dowels, and the slanted floor within the maze housing will also be made out of a single piece of ABS plastic, eliminating the need for the custom formed sheet metal used in the prototype.
- The ball return channel will be much smoother and easier to use on the final design, due to it being a single piece of ABS plastic, rather than the makeshift channel created out of wood for the prototype.
- The batteries will be located within an accessible compartment in the maze housing, rather than being attached to the reverse of the game board as it was for the prototype.

In terms of the electrical system of The Amazing Maze, the final design will have the following changes:

- The final design's Arduino Integrated Circuit components and a LED integrated circuit driver on a custom printed circuit board will replace the prototype's Arduino Uno, BreadBoard, and LED Driver.
- The power supply will be four AA batteries, which supply more current than the two 9V batteries used for the prototype.
- Due to the custom printed circuit board, there will be minimal wiring necessary for the final design.
- The frequency and duration of the fan being on will be decreased from 5 seconds on/5 seconds off, to 3 seconds on/7 seconds off.

Reference List

[1] Ms. Ciurro, Ms. Walsh, and Ms. Williams, March 2015. SEDA Principal, K5 Teacher, and 1-2 Teacher, private communication.

[2] Amazon.com, March 2015, Amazon product search and comparison.

[3] OSHA.gov, March 2015, Materials Handling: Heavy Lifting.

[4] Manufacturers Association for Plastics Processors, Chemical Market Associates Inc., 2010. "ABS Market Report & Survey Result,." http://www.mappinc.com

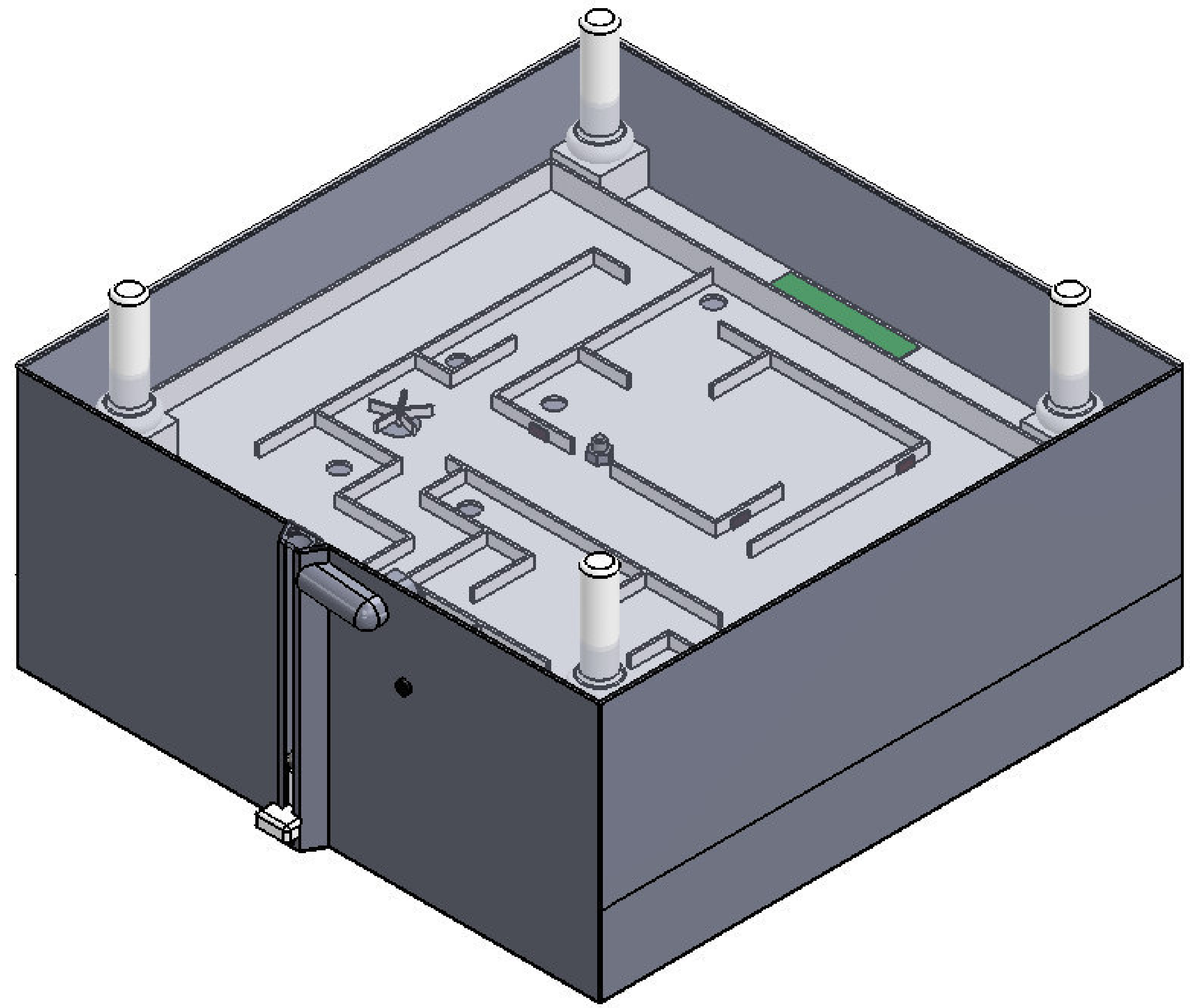
[5] Springfixlinkages.com, May 2015, Mechanical components price research.

[6] Digikey.com, May 2015, Electronic components price research.

[7] Unclesgames.com, May 2015, Wooden Labyrinth comparison.

Appendix A

Contents



WEIGHT: 7.30 LB

PROPRIETARY AND CONFIDENTIAL

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR ± 5°
TWO PLACE DECIMAL ± .02
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5M1994

MATERIAL N/A

FINISH N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JOM	2015MAY9
CHECKED	N/A	N/A
ENG APPR.	N/A	N/A
MFG APPR.	N/A	N/A
Q.A.	N/A	N/A

COMMENTS:

TITLE:

INTERACTIVE MAZE GAME FOR CHILDREN 4-8

SIZE	DWG. NO.	REV
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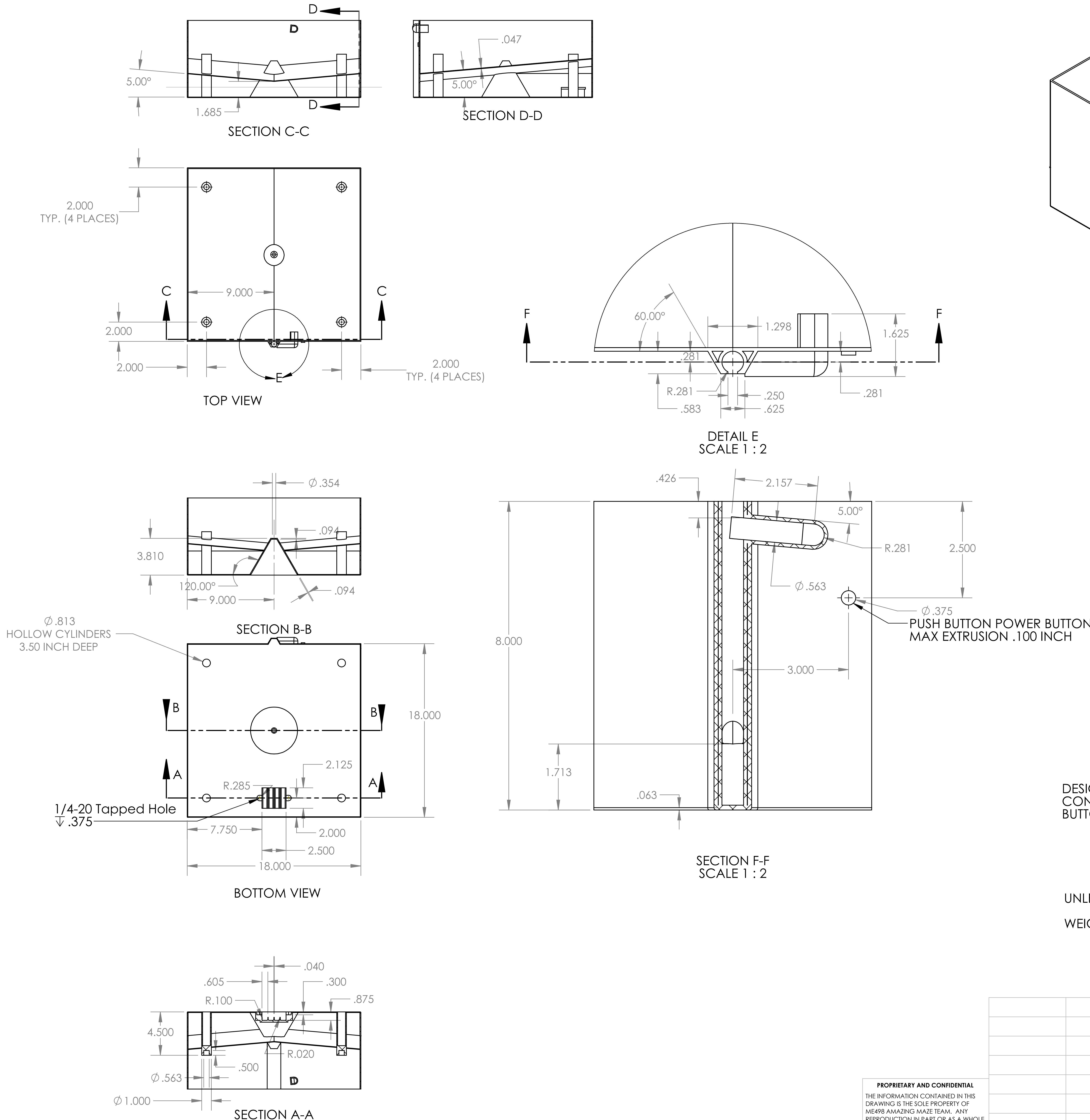
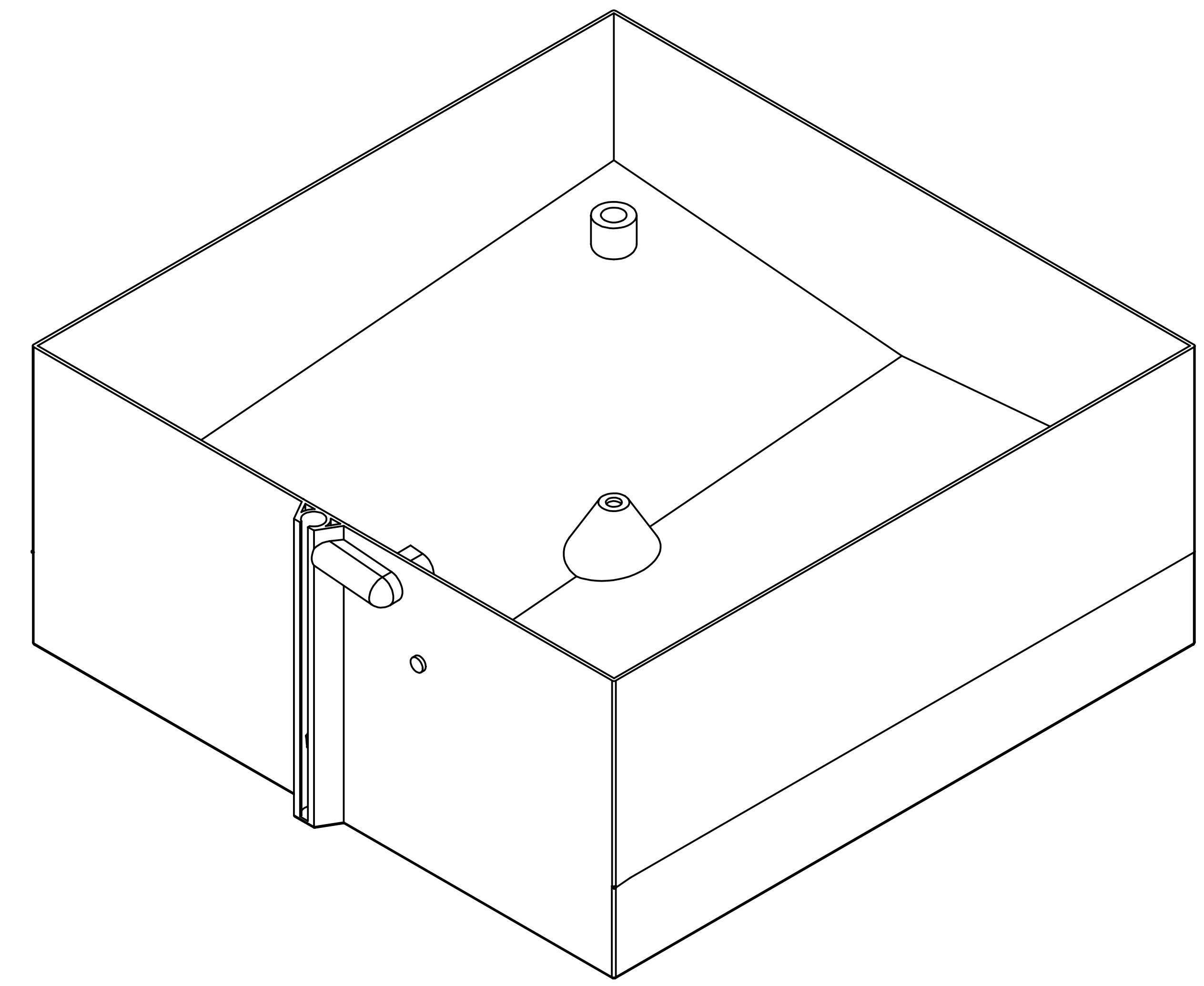
SCALE: 1:1 WEIGHT: SHEET 1 OF 1





DESIGN TO BE PERFORMED BY ELECTRICAL ENGINEERS: CONNECTING BATTERY COMPARTMENT AND POWER BUTTON TO INTEGRATED CIRCUIT MAZE BOARD

UNLESS OTHERWISE SPECIFIED, WALL THICKNESS IS 3/32 IN.

WEIGHT: 3.74 LB

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR ± 5° TWO PLACE DECIMAL ± .02 THREE PLACE DECIMAL ± .005	DRAWN	JOM	2015MAY9
	CHECKED	N/A	N/A
	ENG APPR.	N/A	N/A
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5M1994	MFG APPR.	N/A	N/A
	Q.A.	N/A	N/A
MATERIAL: ABS PLASTIC	COMMENTS:		
FINISH: N/A			
DO NOT SCALE DRAWING			

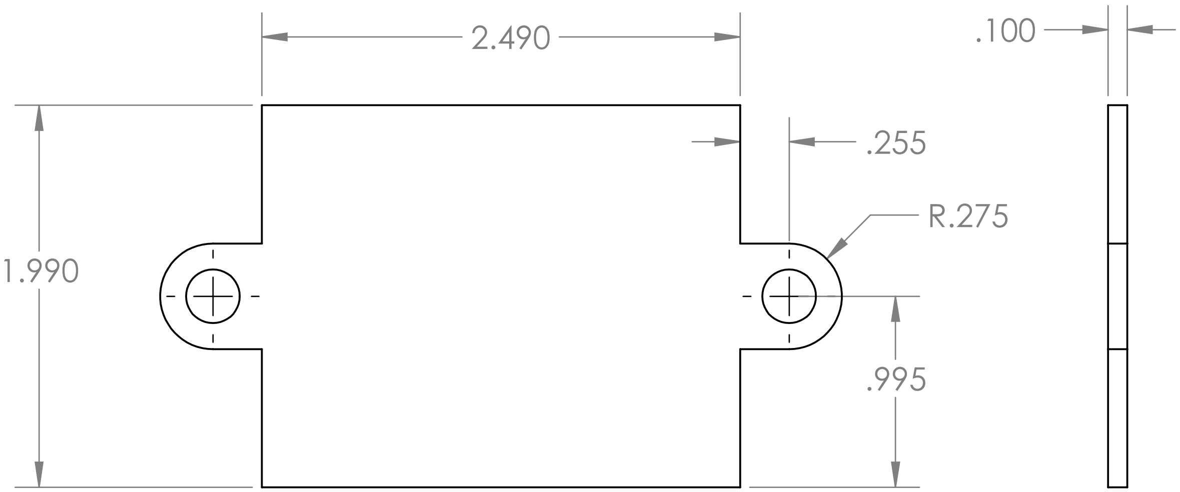
NEXT ASSY	USED ON
APPLICATION	

TITLE:

MAZE HOUSING

SIZE	DWG. NO.	REV
C	MAZE1-1	

SCALE: 1:8 WEIGHT: SHEET 1 OF 1



WEIGHT: 0.02 LB

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF ME498 AMAZING MAZE TEAM. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF ME498 AMAZING MAZE TEAM IS PROHIBITED.

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR ± 5°
TWO PLACE DECIMAL ± .02
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5M1994

MATERIAL
ABS PLASTIC

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JOM	2015MAY9
CHECKED	N/A	N/A
ENG APPR.	N/A	N/A
MFG APPR.	N/A	N/A
Q.A.	N/A	N/A

COMMENTS:

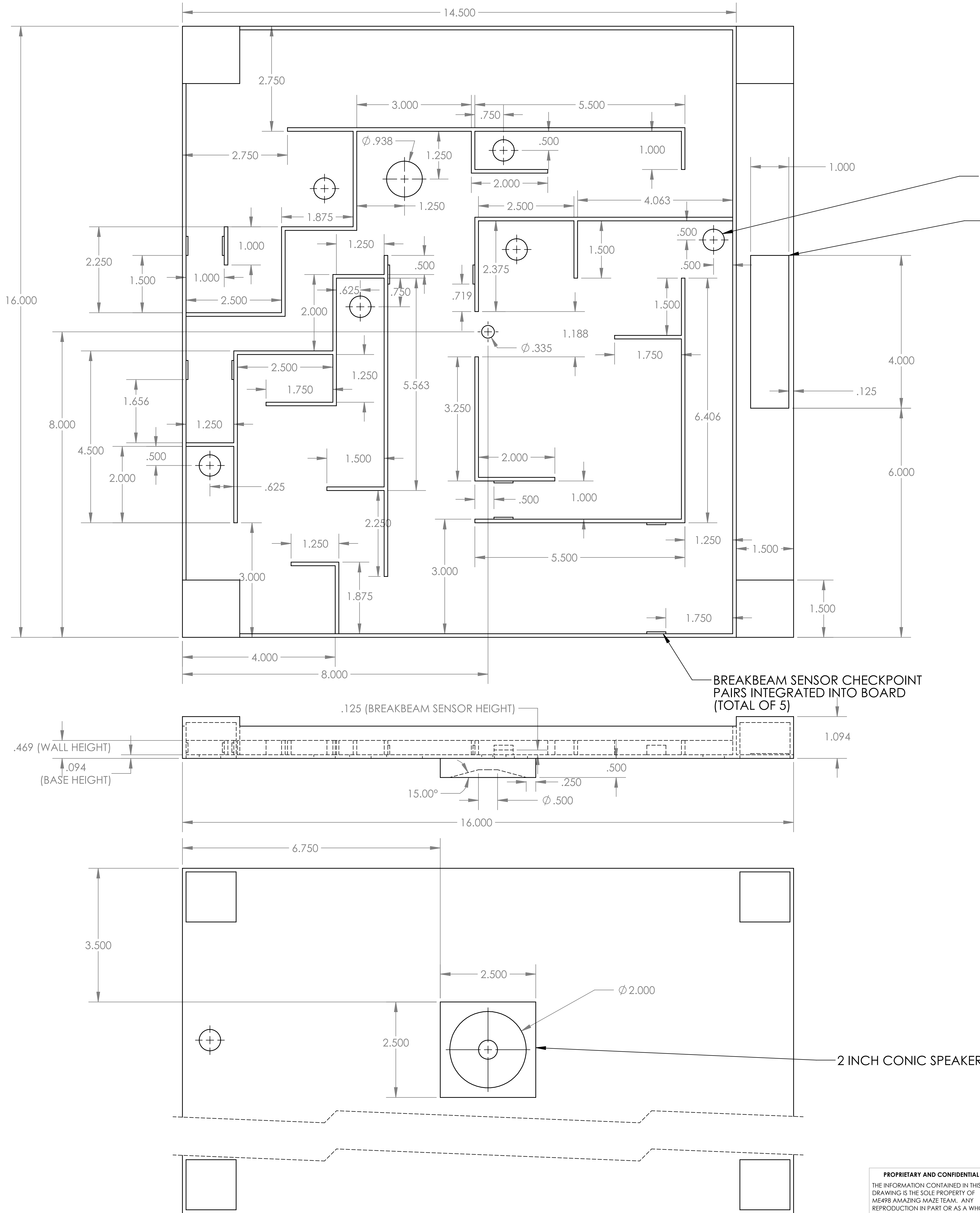
TITLE:

BATTERY COVER

SIZE A | DWG. NO. MAZE1-2 | REV

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

5 4 3 2 1



INTEGRATED CIRCUIT NOTES:

EACH 9/16 DIA HOLE WILL HAVE BREAKBEAM SENSORS BELOW THE BOARD TO SENSE BALL DROPPING.

EACH HOLE WILL ALSO HAVE A RED LED AND A GREEN LED.

EACH BREAKBEAM CHECKPOINT SENSOR PAIR WILL ALSO HAVE A RED LED AND A GREEN LED. RED LED WILL INDICATE CHECKPOINT HAS NOT BEEN REACHED. GREEN LED INDICATES CHECKPOINT FULFILLMENT

CPU WILL CONTROL LOOP PROGRAM

SPEAKER WILL PLAY VARIOUS SOUNDS BASED ON SENSOR FEEDBACK.

POWER WILL BE PROVIDED BY 4 AA BATTERIES INSTALLED IN BASE

ELECTRICAL ENGINEERS WILL DESIGN CIRCUITRY

UNLESS OTHERWISE SPECIFIED, ALL WALLS ARE 3/32 THICK

WEIGHT: 1.33 LB

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR ± 5°
TWO PLACE DECIMAL ± .02
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5M1994

MATERIAL: ABS PLASTIC
FINISH: N/A

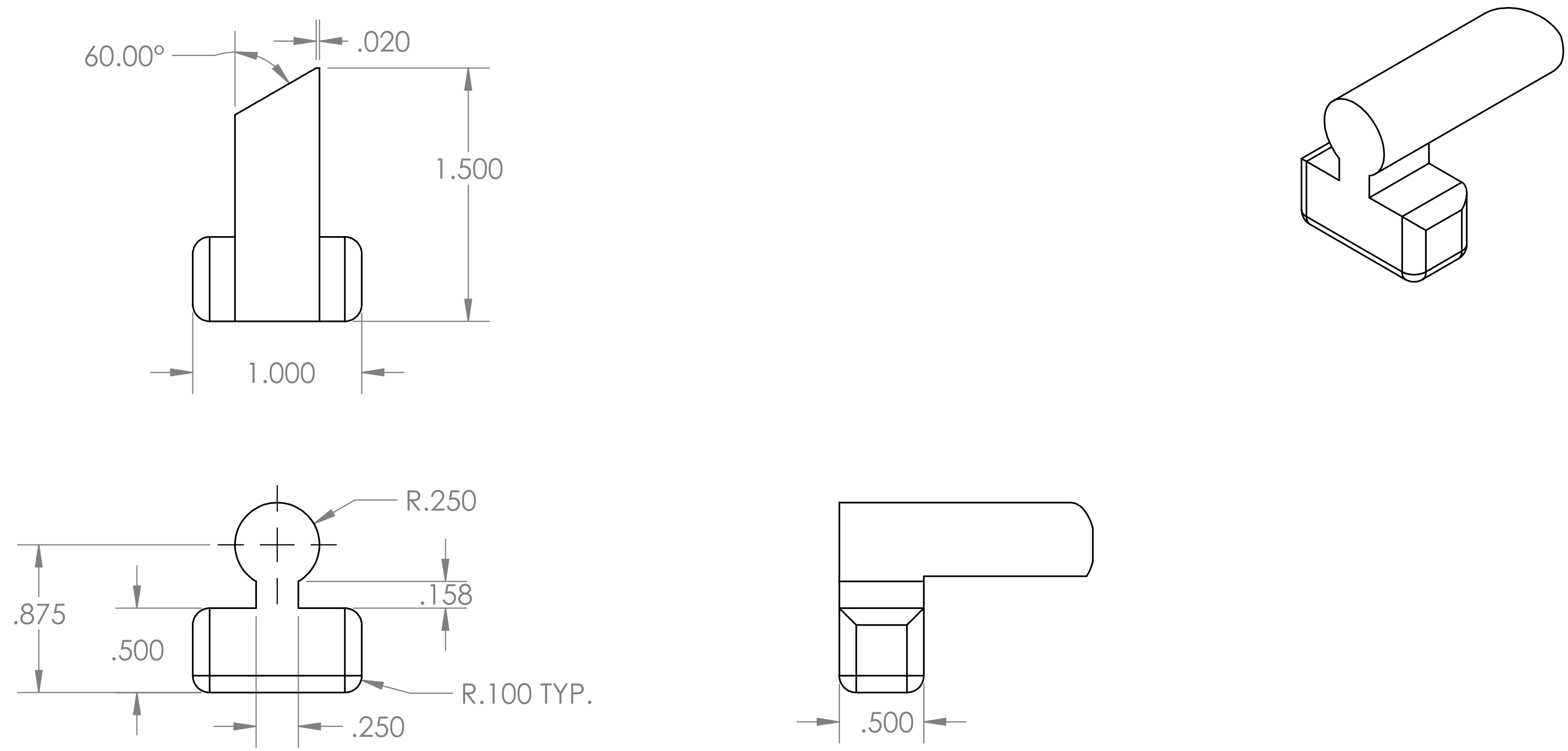
NEXT ASSY | USED ON
APPLICATION | DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JOM	2015MAY9
CHECKED	N/A	N/A
ENG APPR.	N/A	N/A
MFG APPR.	N/A	N/A
Q.A.	N/A	N/A
COMMENTS:		

TITLE: MAZE BOARD WITH INTEGRATED CIRCUIT BOARD

SIZE: C | DWG. NO. MAZE1-3 | REV

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



WEIGHT: 0.04 LB

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
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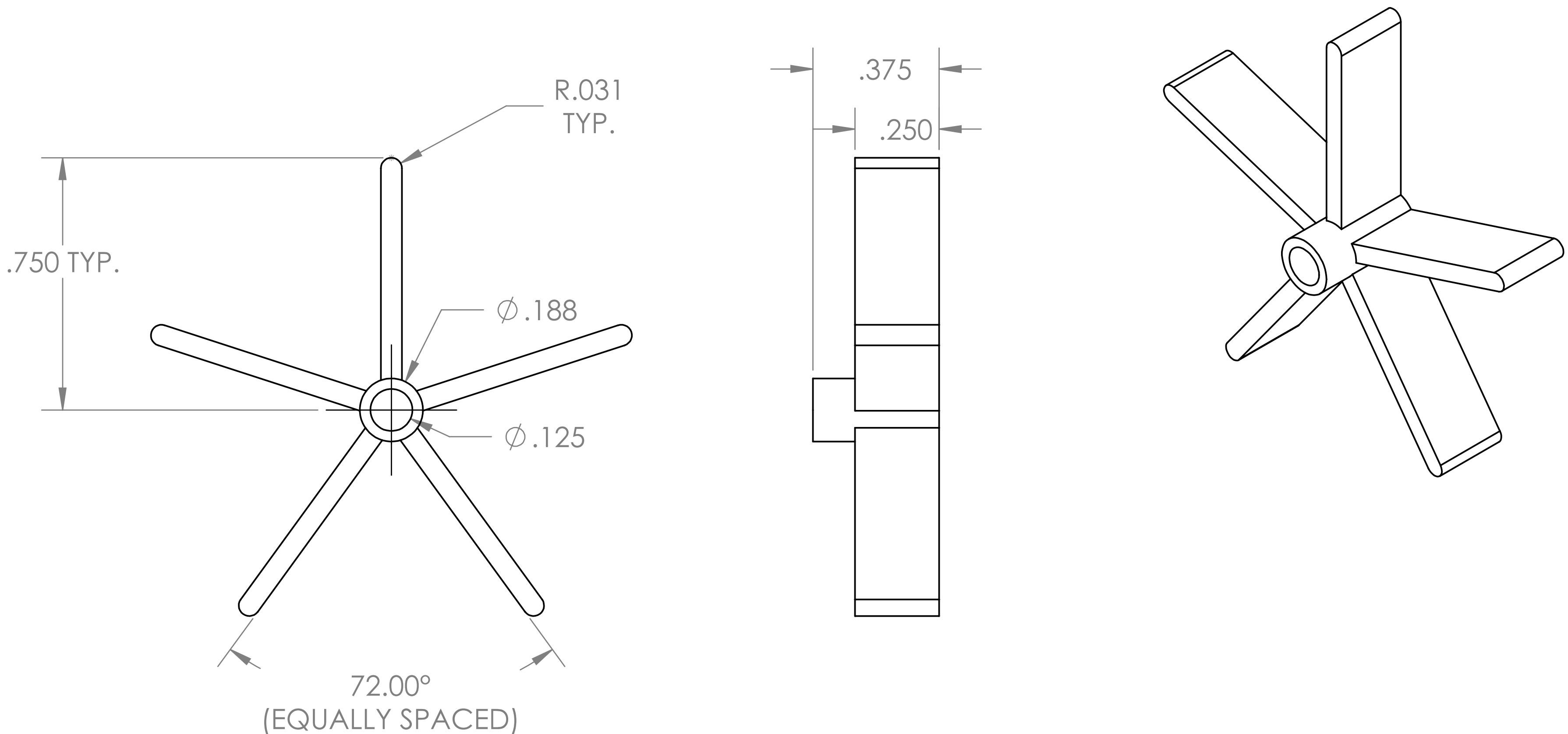
			CHECKED	N/A	N/A	TITLE:
			ENG APPR.	N/A	N/A	BALL RETURN PUSHER
			MFG APPR.	N/A	N/A	
		INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5M1994	Q.A.	N/A	N/A	
		MATERIAL ABS PLASTIC	COMMENTS:			SIZE A DWG. NO. MAZE1-4 REV
NEXT ASSY	USED ON	FINISH N/A				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



WEIGHT: 0.01 LB

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CHECKED	N/A	N/A		
ENG APPR.	N/A	N/A		
MFG APPR.	N/A	N/A		
Q.A.	N/A	N/A		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR ± 5°
TWO PLACE DECIMAL ± .02
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5M1994

MATERIAL
ABS PLASTIC

FINISH
N/A

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
APPLICATION	

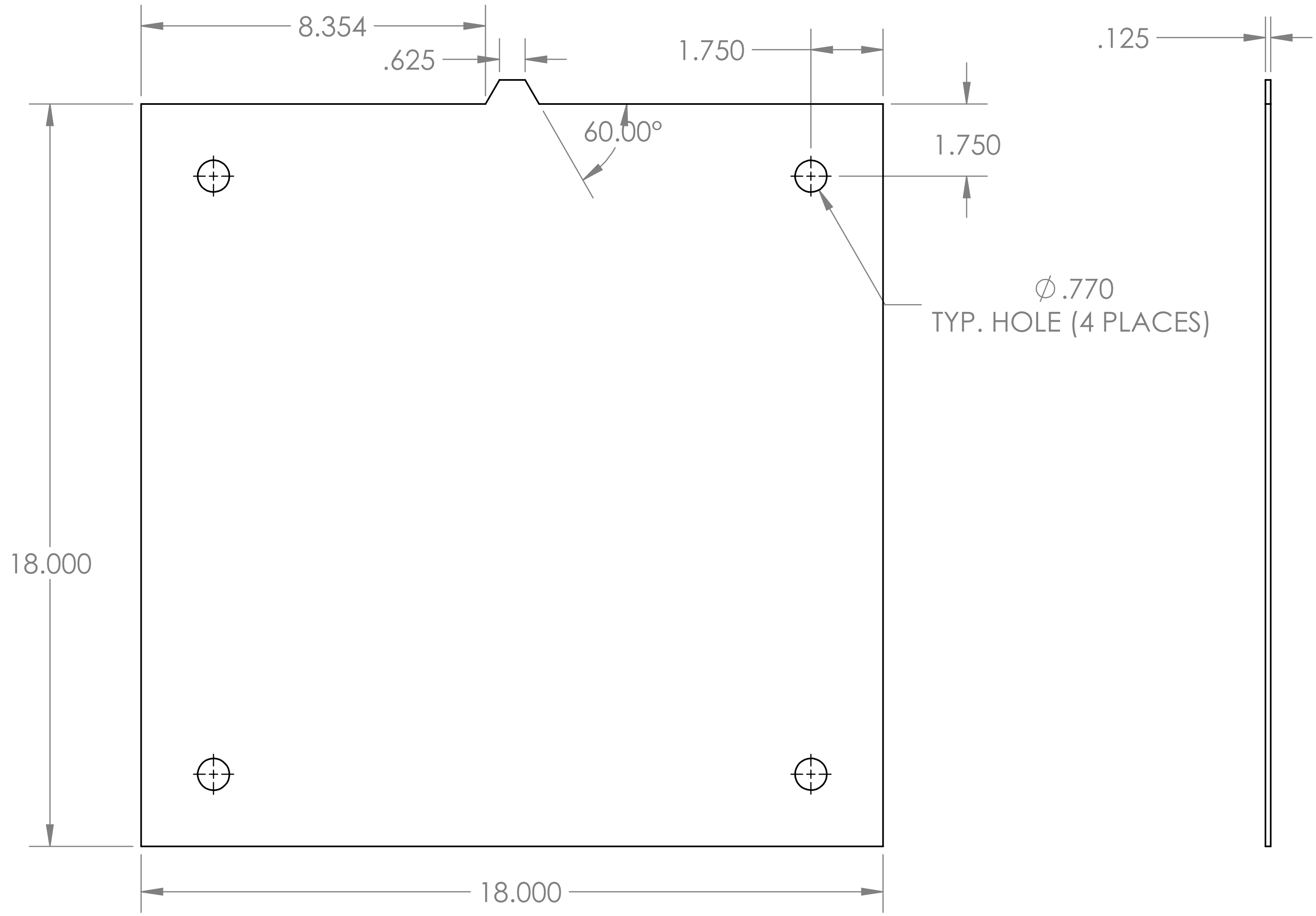
TITLE:

SPINNING OBSTACLE WHEEL

SIZE **A** DWG. NO. MAZE1-5 REV

SCALE: 2:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



WEIGHT: 1.25 LB

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
CLEAR ABS PLASTIC

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JOM	2015MAY9
CHECKED	N/A	N/A
ENG APPR.	N/A	N/A
MFG APPR.	N/A	N/A
Q.A.	N/A	N/A

COMMENTS:

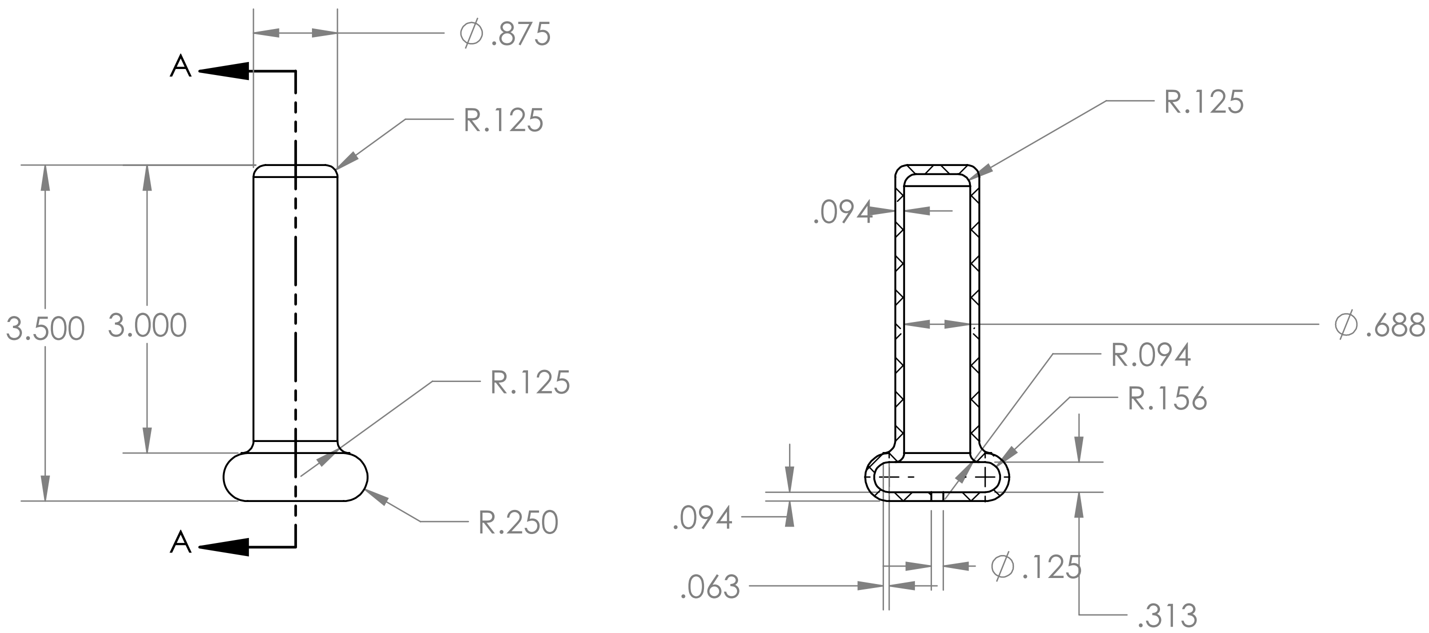
TITLE:

CLEAR MAZE COVER

SIZE A DWG. NO. MAZE1-6 REV

SCALE: 1:8 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



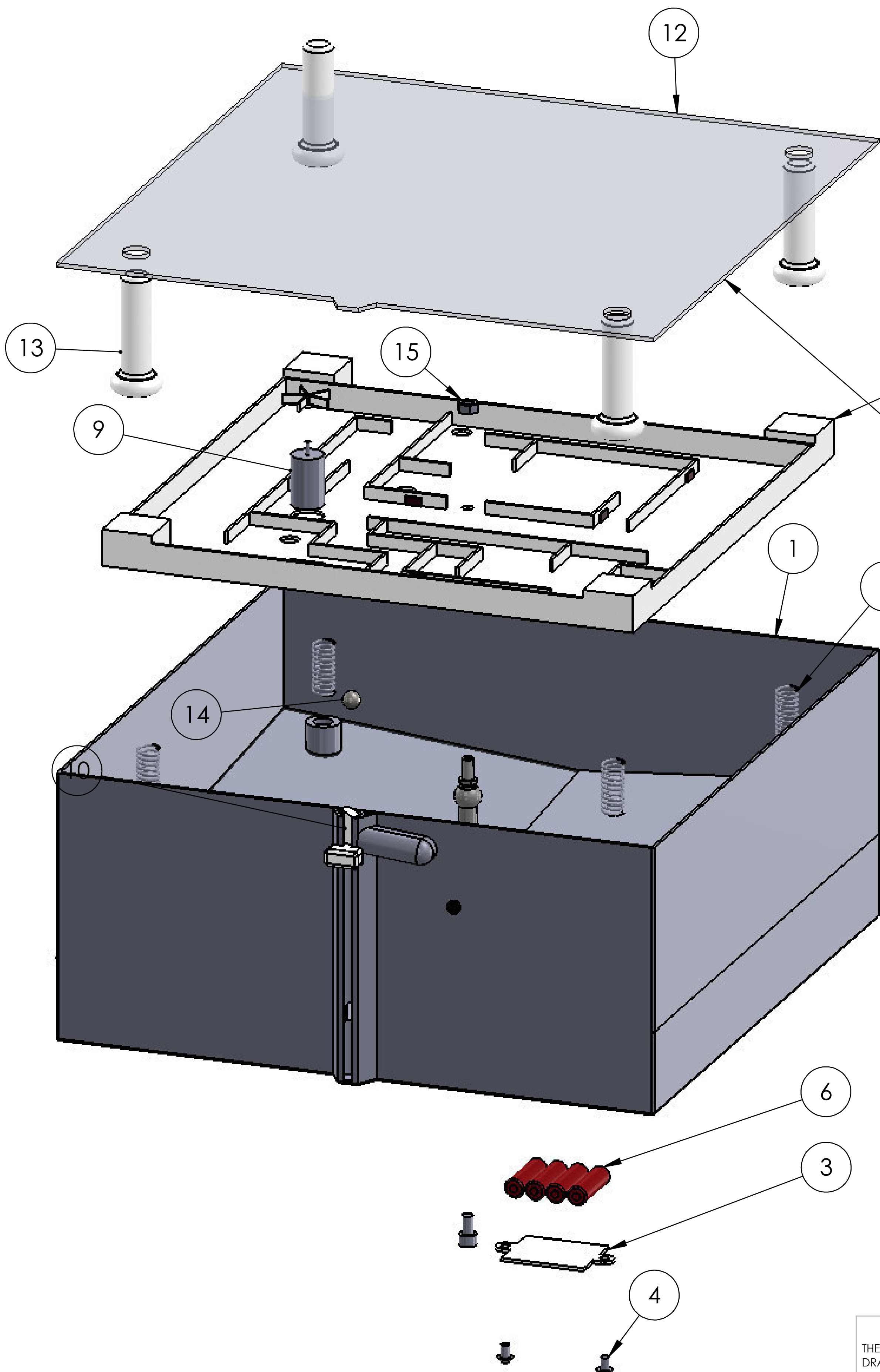
SECTION A-A

WEIGHT: 0.04 LB

UNLESS OTHERWISE SPECIFIED:		NAME	DATE		
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR ± 5° TWO PLACE DECIMAL ± .02 THREE PLACE DECIMAL ± .005	DRAWN	JOM	2015MAY9	TITLE:	
	CHECKED	N/A	N/A	CORNER SPRING COMPRESSOR	
	ENG APPR.	N/A	N/A		
	MFG APPR.	N/A	N/A		
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5M1994	Q.A.	N/A	N/A		
MATERIAL ABS PLASTIC	COMMENTS:			SIZE A	DWG. NO. MAZE1-7 REV
FINISH N/A					
DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT:	SHEET 1 OF 1

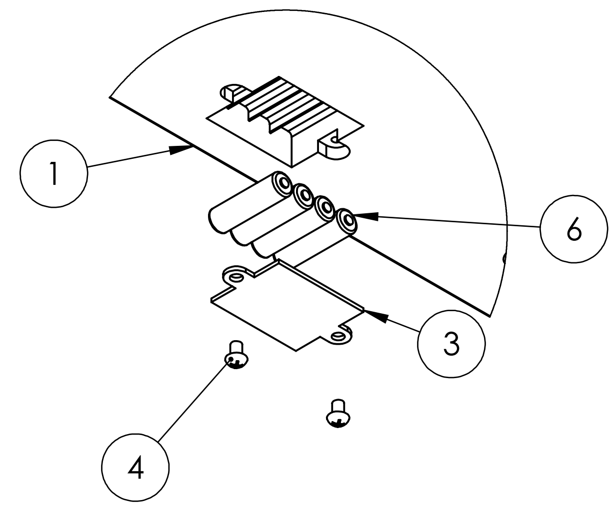
NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1

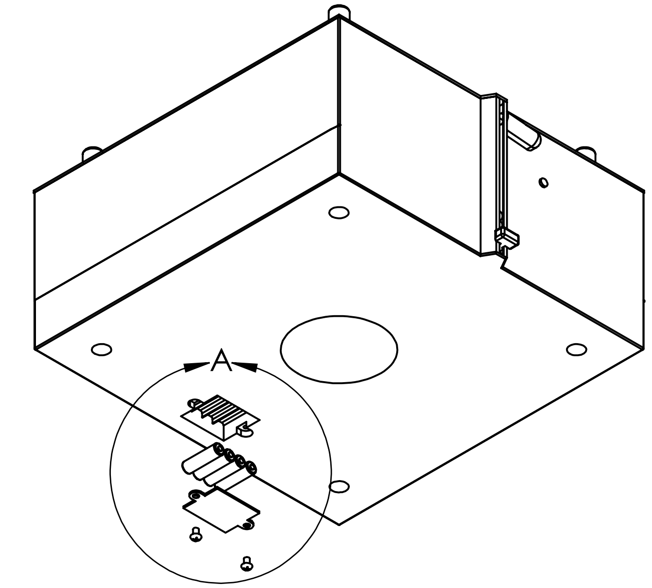


AFTER ASSEMBLY, FUSE CLEAR COVER TO MAZE HOUSING

(BATTERY COMPARTMENT)



DETAIL A
SCALE 1 : 4



WEIGHT: 7.30 LB

ITEM NO.	PART NO.	DESCRIPTION	QTY
1	MAZE1-1	MAZE HOUSING	1
2	R3500.R008sfix	SPRING FIX LINKAGE M8 BALL AND SOCKET JOINT	1
3	MAZE1-2	BATTERY COVER	1
4	0181735	1/4 X .375 ROUND HEAD MACHINE SCREW	2
5	1139649	M8-1.25 X 14MM SHCS (FASTENAL SKU: 1139649)	1
6	AAA BATTERY	AA BATTERY	4
7	88258	1/2 X 1-3/4 COMPRESSION SPRING (MIDWEST FASTENER SKU: 88258)	4
8	MAZE1-3	MAZE BOARD WITH INTEGRATED CIRCUIT BOARD	1
9	273-223	HOBBY MOTOR (RADIOSHACK SKU: 273-223)	1
10	MAZE1-4	BALL RETURN PUSHER	1
11	MAZE1-5	SPINNING OBSTACLE WHEEL	1
12	MAZE1-6	CLEAR MAZE COVER	1
13	MAZE1-7	CORNER SPRING COMPRESSOR	4
14	4RJL1	HALF INCH STEEL BALL (GRAINGER SKU: 4RJL1)	1
15	R3500.R008 NUT	M8 NUT FOR R3500.R008 BALL AND SOCKET JOINT	1

NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR ± 5°
TWO PLACE DECIMAL ± .02
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER: ANSIY14.5M1994

MATERIAL N/A
FINISH N/A
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JOM	2015MAY9
CHECKED	N/A	N/A
ENG APPR.	N/A	N/A
MFG APPR.	N/A	N/A
Q.A.	N/A	N/A

COMMENTS:

TITLE:
EXPLODED MAZE ASSEMBLY

SIZE **B** | DWG. NO. MAZE1-EXPLODED | REV

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

Appendix B

Contents

The following are design alternatives that were considered. Shaded alternatives were selected for the final design.

Board Shape

App-B, Table 1. Board Shape Alternative Designs

Alternatives	Description	Benefits	Drawbacks
Square	Construct the entire game in the shape of a square.	-Easy to store -Easy to design ball movement mechanism	-Shape does not add to the aesthetics of the game
Circle	Construct the entire game in the shape of a circle.	-Attractive aesthetics	-Design of ball movement mechanism will be more complex -Design and construction of game board will be too time consuming
Triangle	Construct the entire game in the shape of a triangle.	-Attractive aesthetics	-Design of ball movement mechanism will be more complex -Corners of game board may be dangerous for young children
Hexagon	Construct the entire game in the shape of a hexagon.	-Attractive aesthetics	-Design and construction of game board will be too time consuming

Ball Movement Mechanism

App-B, Table 2. Ball Movement Mechanism Alternative Designs

Alternatives	Description	Benefits	Drawbacks
Magnetic Stylus	The child will use a magnetic stylus, shaped like a pen with a magnet attached to the end, to pull the ball around the game board. The surface of the game board would need to be enclosed by a transparent material that allows the stylus and the ferromagnetic ball to interact. See Appendix C for diagram.	-Emphasizes the development of fine motor skills -Interactive/challenging method of controlling the ball -Introduces kids to magnets and their uses	-May be too challenging of a task for younger children (4 years) -Would possibly be too easy for older children (8 years) -Would require that the transparent material be thin enough for the magnet to attract the ball, but scratch resistant, in order to maintain good vision of the game board -Would require a ball and magnet pairing that could deliver the desired control of the ball
Dial Mechanism	Using the two dials/knobs mounted on the sides of the maze frame, the child controls how the game board pitches in the two degrees of motion. See Appendix C for diagram.	-Emphasizes the development of fine motor skills -Interactive/challenging method of controlling the ball -Increases the intricacy of the design	-May be too time consuming to design the mechanism that controls the board pitch -Mechanism would require very precise parts in order to be reliable -Complexity and quantity of parts may cause RPC wait time to be longer than 3 weeks -Woodworked components would be too imprecise to deliver consistent performance -Somewhat complex to understand -Hard to incorporate electronics
Ball and Socket Joint	By fixing the center of the game board to a ball and socket joint positioned in the middle of the maze frame, the child can control the pitch of the board by pressing down on the corners of the game board. There will be springs placed under each corner to restore the board to a neutral position after the child presses the corner down.	-Simple mechanism to build -Will deliver consistent results -Durable in construction -Intuitive to understand -Incorporate fine and gross motor skills	-Possibly too simple in design

Maze Layout

App-B, Table 3. Maze Layout Alternative Designs

Alternatives	Description	Benefits	Drawbacks
Random Maze Generator	Use mazegenerator.net to create a randomized maze layout that will be of the appropriate scale for the game board.	-Time effective	-Will not designate areas in the maze for features or obstacles
Original Layout	As a group, design and layout the entire maze, incorporating the desired features and obstacles.	-Optimal placement of each feature and obstacle	-Difficult to quantify results when deciding which layout is more "optimal" -Time consuming
Semi-Random Layout	Use mazegenerator.net to create a general randomized maze layout, but modify it to include the desired features and obstacles in appropriate and convenient locations around the game board.	-Time effective -After investing some thought, can create a layout with optimal placement of each feature and obstacle	-Not 100% original design

Game Board Cover

App-B, Table 4. Game Board Cover Alternative Designs

Alternatives	Description	Benefits	Drawbacks
Plexiglas	Durable, thermoplastic material that is transparent. Will allow children to see the maze, but deny them access to the small, metal ball.	-Durability has been verified through past projects -Relatively low cost	
Inexpensive Clear Material	Inexpensive alternative to Plexiglas that may be found at a local hardware store.	-Lowest cost	-Questionable durability -Questionable transparency -Unknown level of workability (how it will handle hole drilling and mounting)
Glass	An amorphous solid material that is transparent.	-High level of transparency -Improves the overall aesthetics of the maze	-In order to achieve durability goals, the glass would have to be quite thick -Thick sheets of glass are heavy, relative to acrylic alternatives -Thick sheets of glass are more difficult to work with, in regards to drilling holes and mounting it to a wood frame

Ball Return Mechanism

App-B, Table 5. Ball Return Mechanism Alternative Designs

Alternatives	Description	Benefits	Drawbacks
Spinning Spiral	Physically spinning a spiral will carry the ball from the ball collection area, up a column, eventually releasing the ball onto the game board. See Appendix C for diagram.	-Interactive method of retrieving the ball to start the game -Increases aesthetic appeal of the maze -Would be a unique design	-May be too time consuming to design a unique mechanism in the short time frame that we have -Individual components of the spinning spiral would likely require 3D printing, which takes a minimum of 3 weeks -Complexity of parts may increase RPC wait time
Magnetic Ball Retrieval	The child will use a magnetic stylus, shaped like a pen with a magnet attached to the end, to pull the ball from the ball reserve up to the game board. The path from the reserve would be a ramp, all of which would be enclosed by a transparent material. See Appendix C for diagram.	-Emphasizes the development of fine motor skills -Interactive and challenging method of retrieving ball to start the game -Introduces kids to magnets and their uses	-May be too challenging of a task for young children -Would require precise fabrication of the ball channel -Would require a transparent material that is thin enough for the magnet to attract the ball, but durable. -Would require a ball and magnet pairing that could deliver the desired control of the ball.
Guide Rails	Two small guiderails will help corral the ball at the ball reserve and allow the child only to move the ball, which is pinned between the guide rails and the frame of the maze, to the entrance of the maze game board. See Appendix C for diagram.	-Emphasizes the development of fine motor skills -Interactive and challenging method of retrieving ball to start the game -Intuitive method of getting the ball from the ball reserve to the game board	-May be too challenging of a task for young children -Would require precise fabrication of the guide rails, which we might not be capable of doing within our time frame
Silk Sock Squeeze Tube	A silk sock that is fixed to the ball reserve will corral the ball and allow the child to move the ball, with a motion similar to squeezing a tube of toothpaste, to the entrance of the maze game board. See Appendix C for diagram.	-Emphasizes the development of fine motor skills -Interactive and challenging method of retrieving ball to start the game -Produces tactile feedback for the child -Simple design	-Detracts from the aesthetics of the maze -Durability may be an issue -Difficult to fix the sock to the maze in a safe manner (cannot have exposed staples)

RPC Ball Elevator	The ball will enter the elevator shaft at the ball reserve, be pushed upwards by the child via a push rod, and be deposited onto the game board through a hole at the top of the elevator shaft. The parts can be rapid prototyped for best fit.	-Emphasizes the development of fine motor skills -Interactive and challenging method of retrieving ball to start the game -Simple design -Utilize the Rapid Prototyping Center to create accurately made components	-Wait time for RPC parts is three weeks

Ball

App-B, Table 6. Ball Alternatives

Alternatives	Description	Benefits	Drawbacks
Marble	A colorful ball that is lightweight and has a 3/4 inch diameter.	-Colorful ball to manipulate	-Due to small mass, difficult to maneuver through the center feature
Steel Ball	A ferromagnetic ball that is dense, rolls well, and has a diameter of 1/2 inch.	-Is compatible with magnetic features or obstacles -The large mass will help the ball to maneuver through the center feature	

Center Feature Motor Type

App-B, Table 7. Center Feature Motor Type Alternatives

Alternatives	Description	Benefits	Drawbacks
Servo	A servo motor powered center feature will create an obstacle that may imitate the motion of a windshield wiper oscillating between two angles.	-Precise angle control -High torque may move the ball better	-More expensive than similar sized DC motors -Consumes more voltage -Uses 3 pins on the Arduino -Small, fast angle changes -Limited angle of rotation
DC	A DC motor powered center feature will create an obstacle that will spin at a speed based on voltage input for a duration of time.	-Simple programming -Inexpensive -Uses 2 pins on the Arduino	- Slow change of direction -Cannot control the exact orientation of the motor

Additional Unique Features

App-B, Table 8. Unique Feature Alternative Designs

Alternatives	Description	Benefits	Drawbacks
Brush/Complete circuit with ball	The ball, which must conduct electricity, passes through a corridor in the maze that has energized brushes mounted to each side. As the ball completes the circuit between the brushes, LEDs and buzzers are activated.	-Unique design -Uses advanced ideas and technology	-Difficult to design and construct -Questionable reliability -Required materials are expensive
IR sensor activated LEDs	Infrared break-beam sensors will activate LEDs when motion from the ball is detected.	-Simple design and implementation -Utilizes skills and knowledge that we already have -Components are inexpensive	-This feature alone may be too simple and not stimulate the children
Digital Timer	Implement a digital timer that will display the running game time to the children.	-Introduce another visual aspect to the maze -Quick feedback on the duration of the round	-Unfamiliar with programming a digital timer
Dot Matrix Timer	A screen that can create a visual timer by displaying numerals or increasing the number of dots shown by one dot per second.	-Introduce another visual aspect to the maze in the form of increasing the number of dots displayed	-Difficult to know how long the current round has been
7-Segment Timer	A display that is intended to show numerals to the child. Can alternate between game time and game score.	-Introduce another visual aspect to the maze through counting numerals -Quick feedback on the duration of the round -Familiar with programming methods	-Expensive relative to the dot matrix
Checkpoints w/ LEDs	Use IR break beam sensors to create checkpoints that will change a red LED to green and increasing the child's score by one.	-Provides an objective that increases the difficulty for older players -Allows child to problem solve when deciding how to proceed through the game	-This feature alone may be too simple and not stimulate the children
IR Break Beam sensors for "light tunnel"	When the IR break beam sensor detects motion, it illuminates a series of LEDs that light up the corridor that follows the IR sensor.	-Simple design and implementation -Utilizes skills and knowledge that we already have -Components are inexpensive -Provides a unique and	-Programming will be time consuming -Requires specific planning of the game board in order to implement this feature

		rewarding experience to the player	
LED Screen	Keep track of time, display the player's score, and display other sorts of stimulating images that cannot be produced by simpler displays.	-Provides a unique and rewarding experience to the player -Limitless visual elements that can be displayed to the children	-Very complex design and implementation -Utilizes skills and knowledge that we may not already have -Components are expensive
Sound Buzzer	Emits sounds to acknowledge important events like starting the game, passing a checkpoint, successfully finishing the maze, or failing to finish the maze.	-Provides audio feedback -Inexpensive components -Simple programming	-This feature alone may be too simple and not stimulate the children
IR sensor activates timer	Use an IR break beam sensor to initiate and execute the visual timer.	-Reliable method of starting the timer -Inexpensive components -Simple programming	-This feature alone may be too simple and not stimulate the children

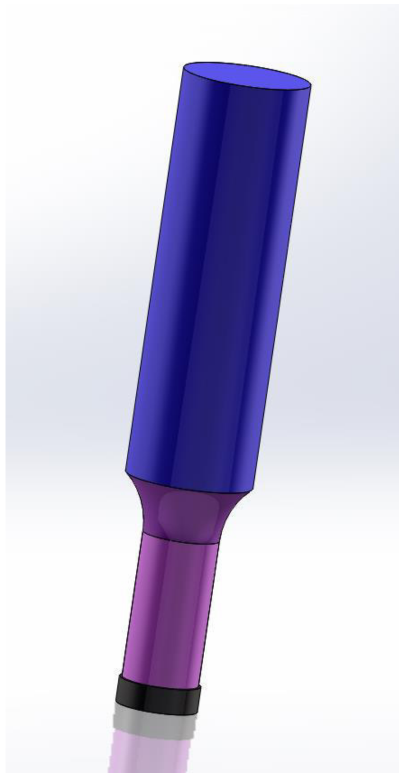
Appendix C

Contents

The following visuals are for the design alternatives that require supplemental description.

Ball Movement Mechanism – Magnetic Stylus

App-C, Figure 1. Magnetic Stylus

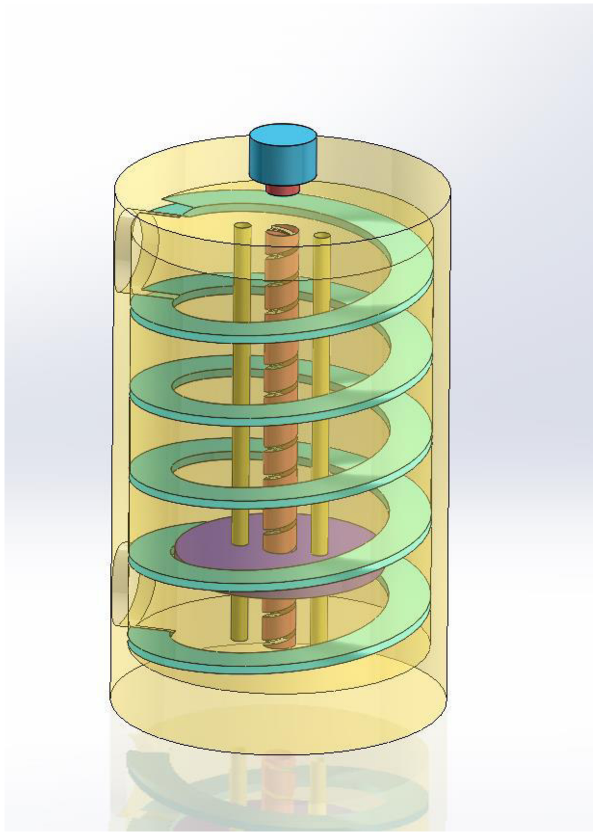


Ball Movement Mechanism – Dial Mechanism

App-C, Figure 2. Dial Mechanism [7]

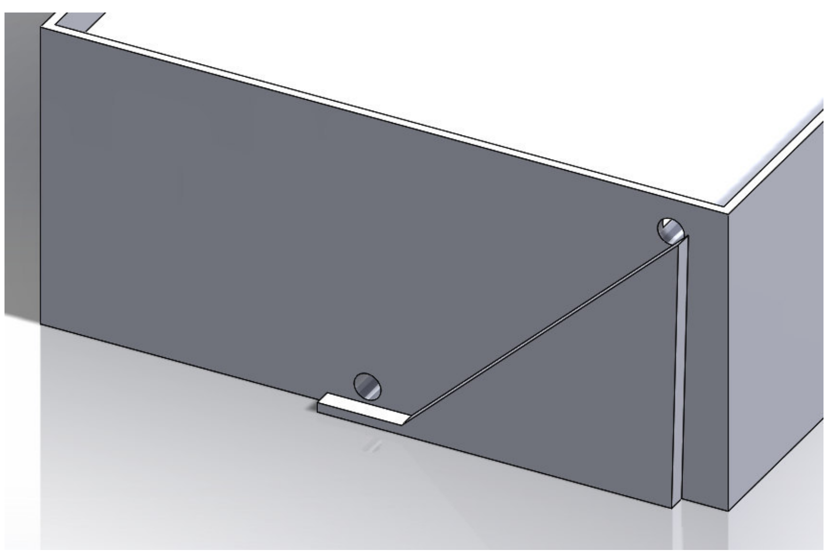
Ball Return Mechanism – Spinning Spiral

App-C, Figure 3. Spinning Spiral



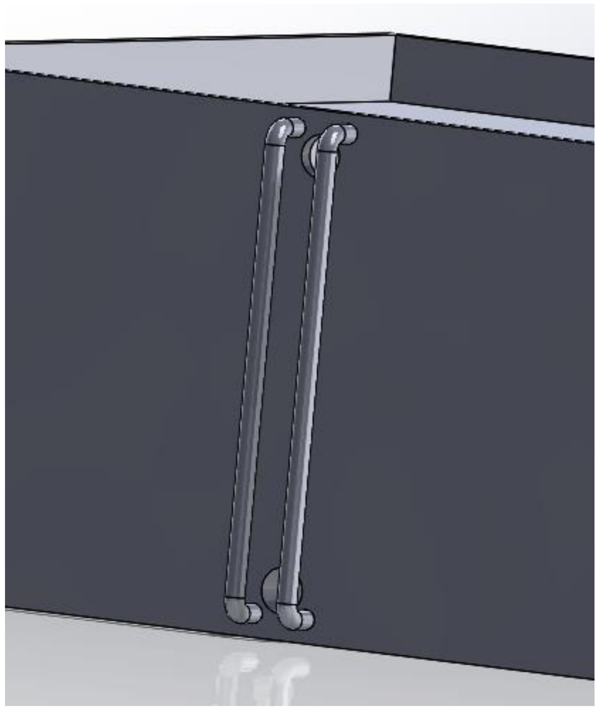
Ball Return Mechanism – Magnetic Ball Retrieval

App-C, Figure 4. Magnetic Ball Retrieval



Ball Return Mechanism – Guide Rails

App-C, Figure 5. Guide Rails



Ball Return Mechanism – Silk Sock Squeeze Tube

App-C, Figure 6. Silk Sock Squeeze Tube