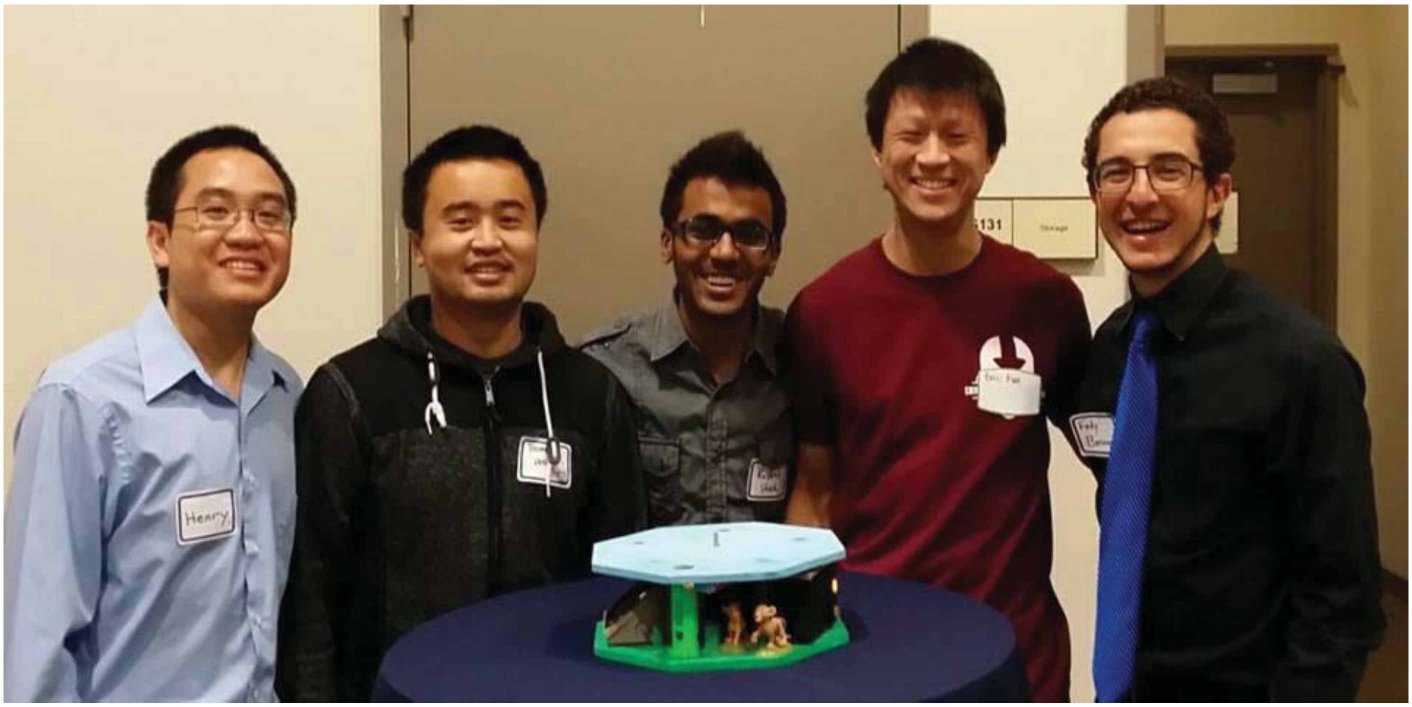
MAE 151 MUSIC BOX DESIGN BINDER: LION KING CHRONICLES



Group 31: Henry, Thomas, Kushal, Eric, Fady

Presented by: Lion King Group (Group #31)

COMPANY: DESIGN WORKS

5200 ENGINEERING HALL

IRVINE, CA 92697-2700

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PHASE 1: CONCEPT DEVELOPMENT

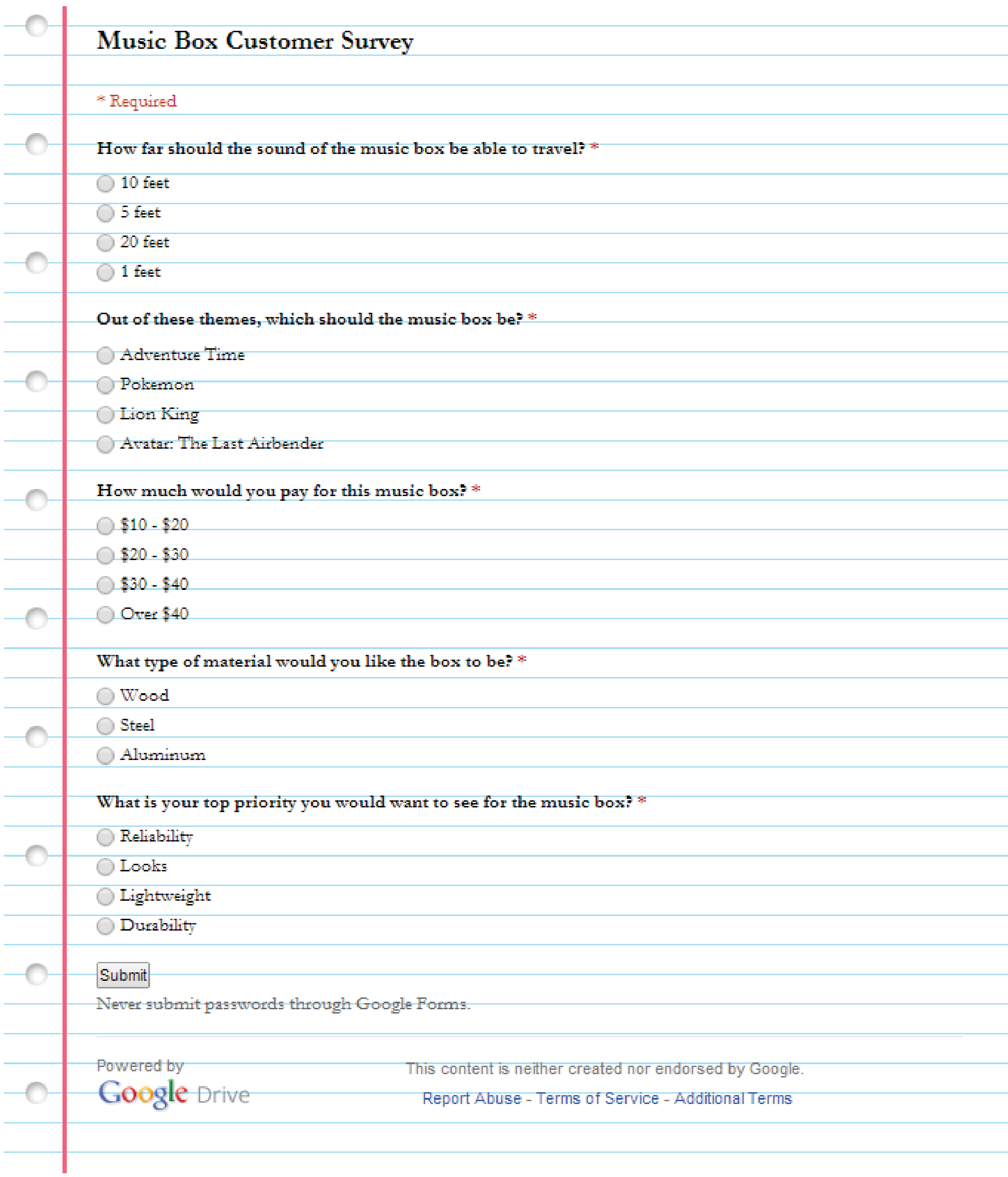
SECTION 1: PROBLEM FORMULATION

Process of Problem Formulation:

In order to define the project definition, first the problem was formulated. The primary problem that was formulated for the project was to design a music box that incorporated ball drop according to customer needs. As a result, the customer need survey was developed and shared throughout the social media to obtain variety of samples of the market. Then, this survey was analyzed and project goal statement and objectives were developed around customer needs.

Customer Need Survey:

This survey was published on the social media websites as twitter and Facebook



Music Box Customer Survey

* Required

How far should the sound of the music box be able to travel? *

- 10 feet
- 5 feet
- 20 feet
- 1 feet

Out of these themes, which should the music box be? *

- Adventure Time
- Pokemon
- Lion King
- Avatar: The Last Airbender

How much would you pay for this music box? *

- $10 - $20
- $20 - $30
- $30 - $40
- Over $40

What type of material would you like the box to be? *

- Wood
- Steel
- Aluminum

What is your top priority you would want to see for the music box? *

- Reliability
- Looks
- Lightweight
- Durability

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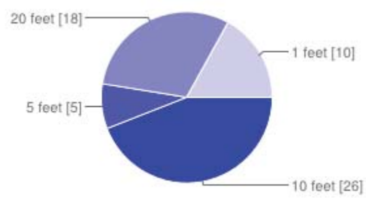
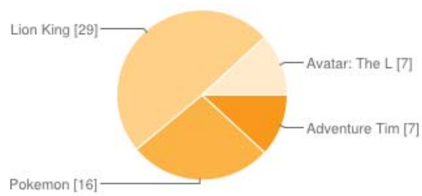
Customer Need Survey Results:

How far should the sound of the music box be able to travel?



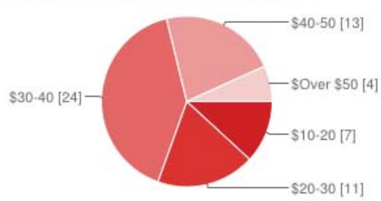
10 feet	26	44%
5 feet	5	8%
20 feet	18	31%
1 feet	10	17%

Out of these themes, which should the music box be?



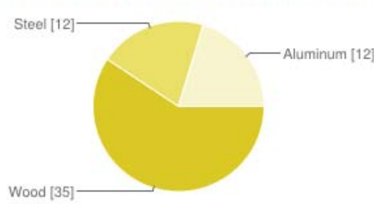
Adventure Time	7	12%
Pokemon	16	27%
Lion King	29	49%
Avatar: The Last Airbender	7	12%

How much would you pay for this music box?



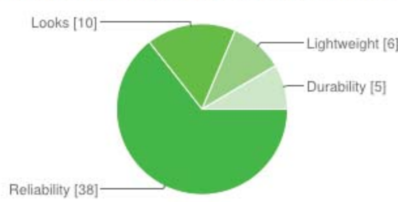
$10-20	7	12%
$20-30	11	19%
$30-40	24	41%
$40-50	13	22%
$Over $50	4	7%

What type of material would you like the box to be?



Wood	35	59%
Steel	12	20%
Aluminum	12	20%

What is your top priority you would want to see for the music box?



Reliability	38	64%
Looks	10	17%
Lightweight	6	10%
Durability	5	8%

Customer Need Summary:

Team was able to narrow down what customers wanted in a music box through the use of an online survey. Throughout the course of a few weeks, approximately 50 people took the survey. From the survey, it was concluded that 44% of the people would like the speaker to be able to be heard 10 feet away, 49% would like the music box to have a Lion King theme, 41% would buy the completed box for $30 - $40 dollars, 59% of the people would like the music box to be made of wood, and 64% would choose reliability as the number one priority of the music box. After analyzing and tabulating data, it was concluded that the following will be customer needs for our music box:

- Lion King Theme
- Wood Material
- Sound loud enough to be heard 10 feet away
- Crisp and clear sound
- Cater to Teens and Preteens; Lovers of The Lion King movie
- Ages 8 – 21 – Majority Survey Takers were in this age range
- Sturdy; Able to handle large loading
- Multiple music box compatibility

SECTION 2: PROJECT DEFINATION

Goal Statement

The goal of this project is to create, design and fabricate a music box that incorporates the theme of customer's choice with the wondrous music created by Composer Dunn-Rankin. The music box will be designed and constructed from scratch, and will be tested for performance before its final design and then final product will be fabricated and presented. In addition, the music box will be designed and programmed in such way that this music box can be integrated into the music box to play a full song with other boxes. In conclusion, this box will satisfy two major requirements: reliability and needs of the customer.

Target audience for this music box are young children in their teens and preteens. The needs of these customers will be determined from method of online survey. Using this survey results, customer needs and specifications will be developed. Our team thinks that a loud and crisp sound produced and lights lit from the music box will entertain children and teens ages 8 to 21 years. In addition, the background of the music box adds a nice theme to any location the customer decides to put the music box. The team also understands that teens and preteens can have reckless tendencies and therefore has also designed the music box to be durable and not collapse or distort under various loadings.

Objectives

1. Produce design concepts and solutions with the specifications and customer needs
2. Down select the design solutions
3. Fabricate a prototype of the selected design
4. Produce electronics and program the controls of the box.
5. Test and Redesign
6. Final Test and Final Presentation

Code of Ethics

- After developing goal statement, code of ethics, presented below was developed.

I. Professional Obligations

Group Lion King shall comply with the customer needs with the highest standards of honor and integrity.

a. Customer needs shall not be altered or distorted if data results are unfavorable.
b. All actions of the Group Lion King shall be recorded and documented weekly in the form of status reports.
c. Group Lion King shall use equipment best fit for the music box as long as it does not conflict with the customer needs or interests.

II. Safety

Group Lion King shall hold paramount the safety, health, and welfare of those involved in the project.

a. Group Lion King shall abide by lab rules of the room when working in the lab; failure to do so will result in leave of lab station.
b. Safety goggles and closed toe shoes shall always be worn as well as sleeves rolled up. Failure to comply will result in leave of lab.
c. If a group member's action(s) is overruled under circumstances that endanger life or project, a different method shall be used to complete the action.
d. Group Lion King shall always use the safest method to manufacture and build the music box.

III. Etiquette

Group Lion King shall treat each other with mutual respect and work together to complete the music box.

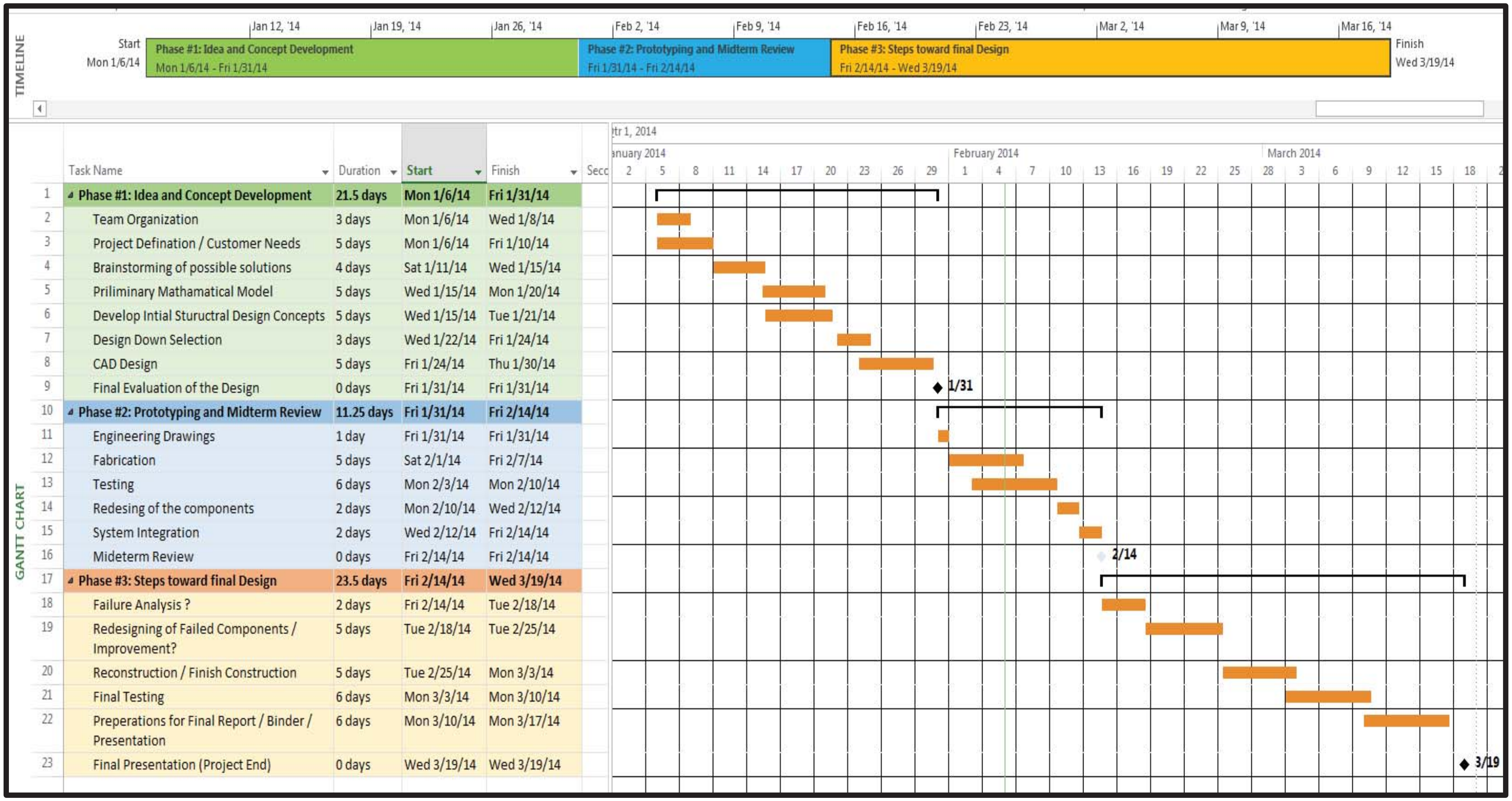
a. If an issue arises, the matter will be dispute in an orderly fashion amongst group members.
b. Attend weekly meetings with group and the teaching assistant. If a group member cannot make it, it is their job to be up to date with project information.
c. Constructive criticism and honest feedback is recommended and welcome. Listen to what other group members have to say to ensure best results for music box.
d. Addition meetings may be schedule if necessary to promote project. Try and find suitable times for all group members if all need to attend.

IV. Time Management

Group Lion King shall assign tasks equally to each of the group members.

a. Group Lion King shall complete assigned tasks by the due date. If they are unable to complete the assigned task by the due date, they shall state when they may complete the assigned task.
b. Group members will help each other complete assignments to meet deadlines and move the project ahead.
c. Don't take on the responsibility of too many tasks if one is unable to complete all of them by the due date.

Preliminary Project Gantt Chart



	Task Name	Duration	Start	Finish
1	Phase #1: Idea and Concept Development	21.5 days	Mon 1/6/14	Fri 1/31/14
2	Team Organization	3 days	Mon 1/6/14	Wed 1/8/14
3	Project Defination / Customer Needs	5 days	Mon 1/6/14	Fri 1/10/14
4	Brainstorming of possible solutions	4 days	Sat 1/11/14	Wed 1/15/14
5	Priliminary Mathamatical Model	5 days	Wed 1/15/14	Mon 1/20/14
6	Develop Intial Stuructral Design Concepts	5 days	Wed 1/15/14	Tue 1/21/14
7	Design Down Selection	3 days	Wed 1/22/14	Fri 1/24/14
8	CAD Design	5 days	Fri 1/24/14	Thu 1/30/14
9	Final Evaluation of the Design	0 days	Fri 1/31/14	Fri 1/31/14
10	Phase #2: Prototyping and Midterm Review	11.25 days	Fri 1/31/14	Fri 2/14/14
11	Engineering Drawings	1 day	Fri 1/31/14	Fri 1/31/14
12	Fabrication	5 days	Sat 2/1/14	Fri 2/7/14
13	Testing	6 days	Mon 2/3/14	Mon 2/10/14
14	Redesing of the components	2 days	Mon 2/10/14	Wed 2/12/14
15	System Integration	2 days	Wed 2/12/14	Fri 2/14/14
16	Mideterm Review	0 days	Fri 2/14/14	Fri 2/14/14
17	Phase #3: Steps toward final Design	23.5 days	Fri 2/14/14	Wed 3/19/14
18	Failure Analysis ?	2 days	Fri 2/14/14	Tue 2/18/14
19	Redesigning of Failed Components / Improvement?	5 days	Tue 2/18/14	Tue 2/25/14
20	Reconstruction / Finish Construction	5 days	Tue 2/25/14	Mon 3/3/14
21	Final Testing	6 days	Mon 3/3/14	Mon 3/10/14
22	Preperations for Final Report / Binder / Presentation	6 days	Mon 3/10/14	Mon 3/17/14
23	Final Presentation (Project End)	0 days	Wed 3/19/14	Wed 3/19/14

Music Box Needs Metrics Matrix

- After analyzing the customer needs, following needs metrics matrix was developed.

Customer Needs	Metrics								
	Maximum Loading	Music Production: Speaker	Sturdy Body	Fail-Safe Mechanism in Case Ball of Malfunction	See Through Pipe to Easily Locate Ball	Lightweight Design	LED Lights for indication	Design Theme Suitable for Ages 8-21	Dimension from the Center Outwards
Lion King Theme		X					X	X	
Made of Wood			X			X			
Loud and Crisp Sound		X							
Compatibility with Other Music Boxes				X					X
Light Effects							X	X	
Reliability	X		X	X	X				X
Withstand Lots of Weight	X		X					X	X

Specification Sheet

#	NEED	METRIC	UNITS	MARGINAL VALUE	IDEAL VALUE
1	Loudness	Hear sound over large distance	Ft	10	25
2	Clear Sound	Music is clear and crisp	Loudness	Loud	Loud, Correct Pitch and no static noise
3	Loading Durability	Able to withstand addition boxes	#	40	50
4	Cost	How much to manufacture	$	40 – 50	30 – 40
5	Weight	How heavy box is	kg	2	Less than 2
6	LED / Photo Sensor	Light up when ball in box	# of Run	50-60	60-80
7	Reliable	Able to withstand 50 continuous ball drops And hold the load	# of Run	50-60	60-80
8	Catch & Release	Time between ball drops	s	±1.5	1.5
9	Visual Appeal	How it looks	Subjective	Clean	Clean and Appealing

Technical Specification Sheet

Music Box Body	
Overall Height, Width, Length	3.94” x 11.81” x 11.81”
Body Material	Plywood
Body Shape	Octagon
Pipe Hole Diameter (Inner and Outer)	1” , 1 1/8”
Pipe Material	Impact-Resistant Polycarbonate
Pipe Shape	Hollow Cylindrical
Dowel Pin Holes (x5)	½”
Dowel Pin Material	Hardwood Dowel
Dowel Pin Shape	Round
Alignment Pin Holes (x2)	¼”
Overall Weight	0.8kg
Steel Ball	
Low Carbon Steel Ball Diameter	0.75”
Speaker	
Brand	Workman Model SA400
Dimensions	4”x4”
Impedance	8Ω
Power	0.5 Watt Max.
Frequency	250 – 5000 Hz
Weight	5oz
Servo	
Overall Height, Width, Length	23mm x 11mm x 29mm
Voltage	3V to 6V DC
Weight	0.005kg
Weight (with Arm)	0.015kg
Speed	0.12sec/60 (at 4.8V)
Torque	1.6 kg-cm / 0.157 N-m
Working Temp	-30C to 60C
Photoresistor Sensor	
Length	4.46mm/0.18in
Width	5mm/0.20in
Height	2.09mm/0.08in
Weight	0.25g/0.01oz
Resistance (Light)	5-10kΩ

Resistance (Dark)	Up to 200kΩ
Voltage	2.5V or higher

Arduino	
Operating Voltage	5V or 3.3V (choice by slide switch)
Clock Speed	16MHz
SRAM	2KB
Flash Memory	32KB
Analog Input Pins	8
Digital I/O Pins	14
DC Jack Input Voltage	7V to 12V. 20V Max.
miniUSB Input Voltage	5V. 5.5V Maximum
Attiny 2313 - 20 PU (8bit)	
Operating Voltages	2.7V to 5.5V
Power Consumption	32kHz, 1.8V
SRAM	128B
PWN Channels	4
Programmable I/O Lines	18
Fully Static Operation	Yes
Endurance	1000 Write/Erase Cycles
Low Power Idle, Standby Mode, Power Down	Yes
Internal Calibrated Oscillator	Yes
Speed Grades	0-10MHz @ 2.7 – 5.5V, 0-20MHz @ 4.5 – 5.5V
Music Instrument Shield	
Codec	VS1053 MP3 and MIDI
Wiring	MIDI Mode
Analog Positive Supply	-0.3V to 3.6V
Digital Positive Supply	-0.3V to 1.85V
I/O Positive Supply	-0.3V to 3.6V
Current at Any Non-Power Pin	±50mA
Operating Temperature	-30C to 85C
Storage Temperature	-65C to 150C
Microphone Input Impedance	45kΩ
Microphone Input Amplifier Gain	26dB
Line Input Impedance	80kΩ
Frequency Response	-0.1dB to 0.1dB

Projected Timeline and Task Assignments for the Project

Task Name	Duration	Start	Finish	Primary Lead	Secondary Lead
Phase #1:Concept Development	**33 days**	**Mon 1/6/14**	**Fri 2/14/14**	**Team**	**Team**
Team Organization	**1 day**	**Mon 1/6/14**	**Mon 1/6/14**	**Kushal**	**Kushal**
Project Shared Document Drive	1 day	Mon 1/6/14	Mon 1/6/14	Kushal	Kushal
Gantt Chart	1 day	Mon 1/6/14	Mon 1/6/14	Kushal	Henry
Project Website	1 day	Mon 1/6/14	Mon 1/6/14	Kushal	Kushal
Project Definition	**14 days**	**Mon 1/6/14**	**Sat 1/11/14**		
Customer Needs	3 days	Mon 1/6/14	Wed 1/8/14	Thomas	Kushal
Project Goal Statement	3 days	Mon 1/6/14	Wed 1/8/14	Thomas	Kushal
Product Specifications	3 days	Wed 1/8/14	Fri 1/10/14	Eric	Kushal
Need Matrix	3 days	Wed 1/8/14	Fri 1/10/14	Eric	Kushal
Structure Design	**9.13 days**	**Fri 1/10/14**	**Mon 1/20/14**	**Team**	**Team**
Brainstorming of the Solutions	3 days	Fri 1/10/14	Mon 1/13/14	Team	Team
Brainstorm Summary	1 day	Mon 1/13/14	Mon 1/13/14	Fady	Kushal
Rough Sketch of the Concepts	3 days	Mon 1/13/14	Wed 1/15/14	Team	Team
Structure Math Model	3 days	Mon 1/13/14	Wed 1/15/14	Kushal	Kushal
Viable Concept Selection	1 day	Wed 1/15/14	Wed 1/15/14	Team	Team
Analysis of Viable Concepts	3 days	Wed 1/15/14	Fri 1/17/14	Team	Team
Downselction	1 day	Fri 1/17/14	Fri 1/17/14	Team	Team
Cad Design	3 days	Fri 1/17/14	Mon 1/20/14	Henry	Kushal
Engineering Drawings	3 days	Fri 1/17/14	Mon 1/20/14	Henry	Kushal
Detect / Catch / Release Design	**9 days**	**Mon 1/20/14**	**Thu 1/30/14**		
Rough Sketch of the Concepts	3 days	Mon 1/20/14	Wed 1/22/14	Team	Team
Ball Kinematics Math Model	1 day	Wed 1/22/14	Wed 1/22/14	Kushal	Kushal
Viable Concept Selection	1 day	Wed 1/22/14	Wed 1/22/14	Team	Team
Analysis of Viable Concepts	3 days	Wed 1/22/14	Fri 1/24/14	Team	Team
Downselction	1 day	Fri 1/24/14	Fri 1/24/14	Team	Team
Cad Design	2 days	Fri 1/24/14	Mon 1/27/14	Henry	Kushal
Engineering Drawings	3 days	Mon 1/27/14	Wed 1/29/14	Henry	Kushal

Internal Theme / Speaker Design	**7 days**	**Fri 1/31/14**	**Mon 2/10/14**		
Rough Sketch of the Concepts	3 days	Fri 1/31/14	Tue 2/4/14	Team	Team
Power Math Model	2 days	Fri 1/31/14	Mon 2/3/14	Kushal	Kushal
Viable Concept Selection	3 days	Mon 2/3/14	Wed 2/5/14	Team	Team
Analysis of Viable Concepts	3 days	Tue 2/4/14	Thu 2/6/14	Team	Team
Downselction	1 day	Thu 2/6/14	Thu 2/6/14	Team	Team
Cad Design	2 days	Fri 1/31/14	Mon 2/3/14	Henry	Kushal
Engineering Drawings	2 days	Fri 2/7/14	Mon 2/10/14	Henry	Kushal
Full Integration of the Design	**5 days**	**Mon 2/3/14**	**Fri 2/7/14**	**Henry**	**Kushal**
Cad Design	5 days	Mon 2/3/14	Fri 2/7/14	Henry	Kushal
Engineering Drawings	5 days	Mon 2/3/14	Fri 2/7/14	Henry	Kushal
Phase #2: Prototyping and Fabrication	**10.5 days**	**Fri 1/31/14**	**Thu 2/13/14**	Team	Team
Main Structure Fabrication	1 day	Fri 1/31/14	Fri 1/31/14	Eric	Henry
Music Electronic Fabrication	5 days	Mon 2/3/14	Fri 2/7/14	Fady	Kushal / Thomas
Music Programming	1 day	Fri 1/31/14	Fri 1/31/14	Kushal	Thomas / Fady
Detect / Catch / Release Electronics	1 day	Wed 2/5/14	Wed 2/5/14	Thomas	Kushal / Fady
Detect / Catch / Release Programming	1 day	Wed 2/5/14	Wed 2/5/14	Thomas	Kushal / Fady
Internal Theme Electronics	3 days	Fri 2/7/14	Tue 2/11/14	Fady	Kushal / Thomas
Internal Theme Programming	2 days	Fri 2/7/14	Mon 2/10/14	Fady	Kushal / Thomas
Internal Theme Fabrication	1 day	Tue 2/11/14	Tue 2/11/14	Henry	Eric
Internal Theme Painting	1 day	Wed 2/12/14	Wed 2/12/14	Henry	Eric
System Integration	4 days	Mon 2/10/14	Thu 2/13/14	Henry	Eric
Midterm Review	0 days	Thu 2/13/14	Thu 2/13/14	Team	Team
Phase #3: Steps toward final Design	**26 days**	**Thu 2/13/14**	**Wed 3/19/14**	**Team**	**Team**
Redesigning of Failed Components / Improvement?	6.25 days	Fri 2/14/14	Fri 2/21/14	Team	Team
Reconstruction / Finish Construction	5 days	Mon 2/24/14	Fri 2/28/14	Team	Team
Final Testing	6 days	Fri 2/28/14	Fri 3/7/14	Team	Team
Preparations for Final Report / Binder / Presentation	6 days	Fri 3/7/14	Fri 3/14/14	Team	Team
Final Presentation (Project End)	0 days	Wed 3/19/14	Wed 3/19/14	Team	Team

Brainstorming / Concepts Generation

- Before moving to design concept development, brainstorming session was performed and following notes were taken:

Themes:

- Lion King (Henry)
  - Toy figurines of characters
    - Servo to move figurines, recreating first scene
  - Pride Rock
  - Yellow LEDs to simulate sunset
- Avatar the Last Air bender (Eric)
  - LEDs of 4 different elemental symbols
  - Lights fade in and out
- Pokémon (Kushal)
  - Poke balls Theme
  - LED strips shooting out from sides to simulate Poke balls opening
- Adventure Time (Thomas)
  - Drawing/painting with LEDs
  - AT Logo lit up with LEDs
- Doctor Who
  - Blue police call box (TARDIS) with blue LED on top
    - Motor that spins the blue box
  - Outer space background

Structure:

- Top and bottom plates dimensions given
- Wooden dowels around the sides
- See SolidWorks models for different structural layouts

Ball Detection Methods:

- Actuated switch (Henry)
- Magnetometer (Eric/Kushal)
- Push Switch (Kushal)
- LED and Photo resistor (Thomas/Fady)

Ball Catch/Release Methods:

- Metal plate rotated into place by servo to partly block path (Henry)
- Plate opens or closes by servo to completely block path (Eric)
- Electromagnet to keep the ball from moving (Eric)
- Servo arm to block path (Kushal)
- Spring and solenoid (Kushal/Thomas)
- Plate opens or closes by solenoid to completely block path (Fady)

Ball Movement:

- Straight pipe down (Henry/Eric/Thomas)
- Angled pipe down (Eric)
- Vertical pipes at entrance and exit, with angled pipes in between (Kushal)
- Metal track along which ball rolls (Fady)

SECTION 3: STRUCTURE DESIGN CONCEPT

Music Box Structure Design Process Summary

- Goal: To create concept design of the structure part of the music box

- In order, to achieve this goal, following procedure was followed.
  - *Structure Design Concept Process:*
    - Structure Customer Needs and Specification discussed and analyzed
    - Brainstormed few possible solutions
    - Mathematical model developed
    - Sketches of possible solutions generated and selected five design concepts
    - 5 design concepts analyzed for their performance and the cost
    - Performed down selection and finalized the design
    - Engineering drawings produced.
    -

- Primary Design Parameters that were obtained for the final Design are:
  - Theoretical Mass: 0.83 kg
  - True Mass: 0.80 kg
  - # of wooden post : 6
  - Maximum Stress: 5.61 MPa
  - Total Cost: $2.66
  - Numbers of Parts to be cut = 8 sides, 5 wooden posts.
  - Joint Method: Wood Glue

Structure Mathematical Model:

- This mathematical model was developed to understand and quickly calculate numbers of posts or plates required for given load. This was utilize to come up with viable solutions and design concepts for the music box.
    - **Calculation of the stress**
        - To calculate the applied stress of one post, the following equations were used.

$$\sigma_{Applied} = \frac{F_{Applied}}{A_{Cross\ Sectional}}; \qquad F_{Applied} = \frac{Total\ Loading}{\#\ of\ Posts\ or\ Plates}$$

    - **Calculation of the allowable and applied bucking force**
        - To calculate the buckling force of one post, the following buckling equation was used:

$$F_{buckling} = \frac{\pi EI}{(KL)^2}; \qquad \sigma_{buckling} = \frac{F_{Buckling}}{A_{Cross\ Sectional}}$$

Where,

F = Force in N,

E = modulus of elasticity = 9x109 Pa,

I = area moment of inertia,

L= unsupported length of column = 0.1 m,

K = column effective length factor = 1 for this application

- In order to find the moment of inertia of for the post, we must use the equation:

Where,

r=the radius of the post

- **Failure Criteria:**
    1. Principle Stress and Yield Stress Comparison:

$$\sigma_1 < \sigma_Y$$

    2. Bucking Force and Applied Force

$$F_{Applied} < F_{Buckling}$$

    3. Factor of Safety:

$$Factor\ of\ Safety\ (FS) = \frac{Material\ Strength}{Design\ Load} = \frac{\sigma_Y}{\sigma_1}$$

- Using this equations, diameter of the posts and the number of the posts were varied and the results were obtained and were tabulated as shown below.

Math Model Results and Comparisons:

Total Loading (N)	Number of Posts	Diameter of the Post (in)	Length of the Post (cm)	Cost $	Elastic Module	Diameter of the Post (m)	Length of the Post (m)	Area of the Post (m^2)	Second Moment of Inertia (I or	Distibute the Load per Post (N / Post)	Area of the Post (mm^2)	Normal Stress on the Post (Mpa)	F.S	Effective Length	Maximum Buckling Force (N)	Maximum Buckling Stress (Mpa)
850	1	0.25	10	$0.09	8.00E+09	0.00635	0.1	3.17E-05	1.60E-10	850	31.67	26.840	0.56	1	1260	40
850	1	0.5	10	$0.13	8.00E+09	0.0127	0.1	1.27E-04	2.55E-09	850	126.68	6.710	2.24	1	20165	159
850	1	0.75	10	$1.69	8.00E+09	0.01905	0.1	2.85E-04	1.29E-08	850	285.02	2.982	5.03	1	102087	358
850	1	1	10	$2.09	8.00E+09	0.0254	0.1	5.07E-04	4.09E-08	850	506.71	1.677	8.94	1	322645	637
850	2	0.25	10	$0.18	8.00E+09	0.00635	0.1	3.17E-05	1.60E-10	425	31.67	13.420	1.12	1	1260	40
850	2	0.5	10	$0.26	8.00E+09	0.0127	0.1	1.27E-04	2.55E-09	425	126.68	3.355	4.47	1	20165	159
850	2	0.75	10	$3.39	8.00E+09	0.01905	0.1	2.85E-04	1.29E-08	425	285.02	1.491	10.06	1	102087	358
850	2	1	10	$4.17	8.00E+09	0.0254	0.1	5.07E-04	4.09E-08	425	506.71	0.839	17.88	1	322645	637
850	3	0.25	10	$0.27	8.00E+09	0.00635	0.1	3.17E-05	1.60E-10	283	31.67	8.947	1.68	1	1260	40
850	3	0.5	10	$0.39	8.00E+09	0.0127	0.1	1.27E-04	2.55E-09	283	126.68	2.237	6.71	1	20165	159
850	3	0.75	10	$5.08	8.00E+09	0.01905	0.1	2.85E-04	1.29E-08	283	285.02	0.994	15.09	1	102087	358
850	3	1	10	$6.26	8.00E+09	0.0254	0.1	5.07E-04	4.09E-08	283	506.71	0.559	26.83	1	322645	637
850	4	0.25	10	$0.36	8.00E+09	0.00635	0.1	3.17E-05	1.60E-10	213	31.67	6.710	2.24	1	1260	40
850	4	0.5	10	$0.52	8.00E+09	0.0127	0.1	1.27E-04	2.55E-09	213	126.68	1.677	8.94	1	20165	159
850	4	0.75	10	$6.77	8.00E+09	0.01905	0.1	2.85E-04	1.29E-08	213	285.02	0.746	20.12	1	102087	358
850	4	1	10	$8.35	8.00E+09	0.0254	0.1	5.07E-04	4.09E-08	213	506.71	0.419	35.77	1	322645	637
850	5	0.25	10	$0.45	8.00E+09	0.00635	0.1	3.17E-05	1.60E-10	170	31.67	5.368	2.79	1	1260	40
850	5	0.5	10	$0.65	8.00E+09	0.0127	0.1	1.27E-04	2.55E-09	170	126.68	1.342	11.18	1	20165	159
850	5	0.75	10	$8.46	8.00E+09	0.01905	0.1	2.85E-04	1.29E-08	170	285.02	0.596	25.15	1	102087	358
850	5	1	10	$10.43	8.00E+09	0.0254	0.1	5.07E-04	4.09E-08	170	506.71	0.335	44.71	1	322645	637
850	6	0.25	10	$0.54	8.00E+09	0.00635	0.1	3.17E-05	1.60E-10	142	31.67	4.473	3.35	1	1260	40
850	6	0.5	10	$0.78	8.00E+09	0.0127	0.1	1.27E-04	2.55E-09	142	126.68	1.118	13.41	1	20165	159
850	6	0.75	10	$10.16	8.00E+09	0.01905	0.1	2.85E-04	1.29E-08	142	285.02	0.497	30.18	1	102087	358
850	6	1	10	$12.52	8.00E+09	0.0254	0.1	5.07E-04	4.09E-08	142	506.71	0.280	53.65	1	322645	637

- The table above was created to aid the concept design process. This was developed so the values can be kept in mind when creating a design concept for the structure.

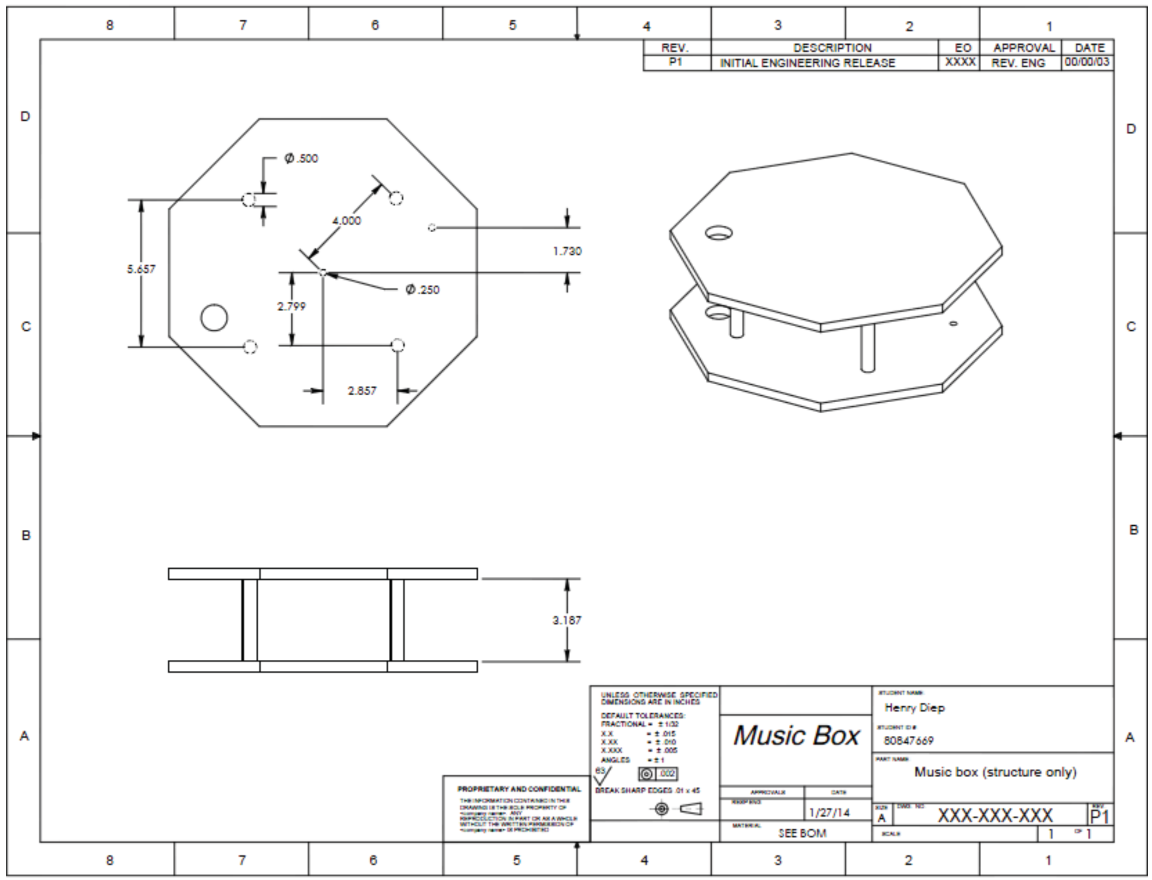
Design Concepts:

- Few design concepts were generated by the team and they are presented below.

Henry Diep's Structure Design

Detailed Structure Design # 1

➢ **Images:**



Design #1 Specifications Details:

- **Mass**: The box contains 0.7902 kg
- **Strength**:

Maximum Stress (MPa)	2.372
Maximum Displacement (mm)	0.152
Maximum Displacement (mm) Due to Buckling Study	10.5

- **Ease of Manufacturing**: Very easy to manufacture. Cut respective lengths from stock dowel purchased from Home Depot/Lowes/Ace or from woodshop.
- **Visual Criteria**: Clean, spacious
- **Reliability**: The factor of safety under tensile loading of top plate is 5.8. (13.8 is UTS & 2.372 is max tensile stress)
- **Material Properties**:

Top / Bottom Plate		Wooden Dowel - Birch (1st choice)	
Elastic Module (kgf / cm^2)	63222.02	Elastic Module (kgf / cm^2)	168253
Poisons ratio (N/A)	0.22	Poisons ratio (N/A)	0.3
Density (kg / cm^3)	0.000544	Density (kg / cm^3)	0.00061
Compression Strength (Mpa)	10 to 24	Compression Strength (Mpa)	100

Why chosen material for posts?

BIGGER YOUNG'S Modulus allows a higher tolerable critical load for buckling. The buckling equation: P=n (pi^2) EI/L^2. A higher value of E (Young's Modulus), the higher the max load before buckling occurs is obtained. Birch had the higher value of E than poplar, the two commercial sold dowel pins that were wood-based (for low density)

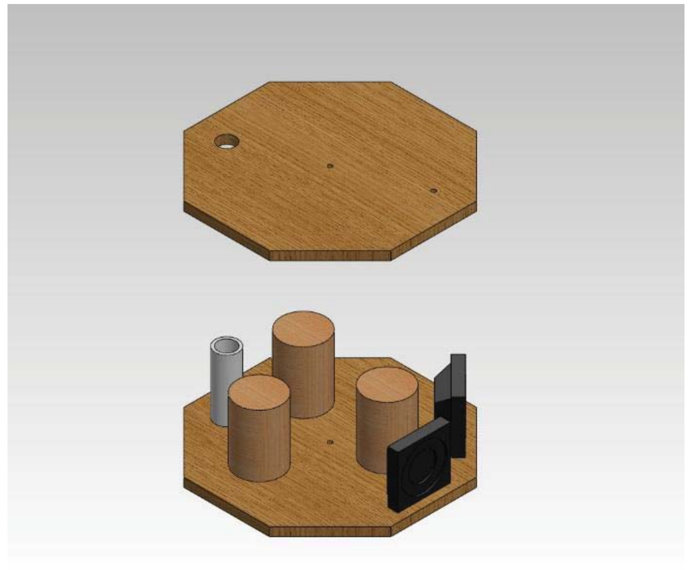
- **BOM**:

Item / Description	Size	Qty	Unit Price	Total price
Birch Wood Dowel [Home Depot]	0.5 in Diameter x 36 in	1	$1.11	$1.11
Plywood Plate	12x12x11/32 in	2	$1	$2
Dowel Pin	1/4 in	1	$0.25	$0.25
Total Cost				$3.36

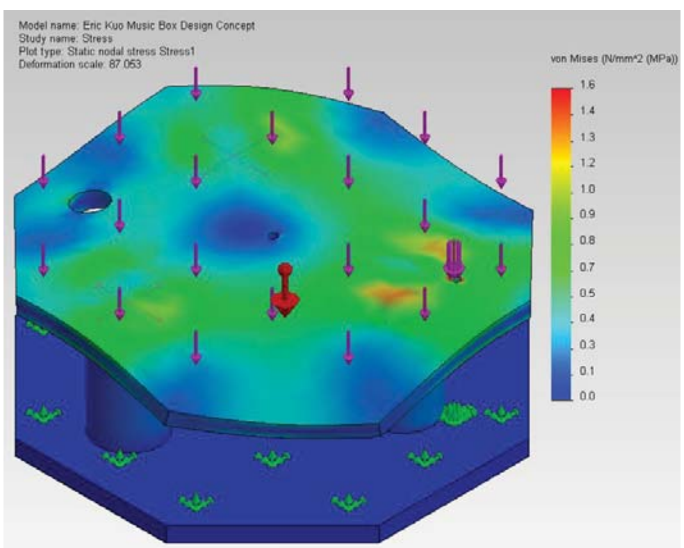
Eric's Structure Design

Detailed Structure Design # 2

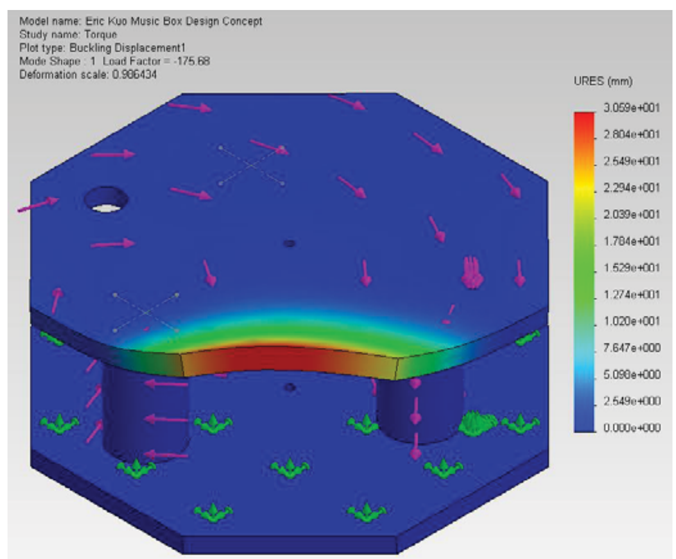
Images:



Stress Test:



Torque Test:



Design #2 Specifications Details:

- **Weight:** 2.4 kg
- **Strength:**

Maximum Stress (MPa)	1.6
Maximum Displacement (mm)	3
Maximum Displacement (mm) Due to Torque	2.5

- **Ease of Manufacturing:** Manufacturing the box would only require cutting out the two base plates and slots to insert the pillars to connect the two plates together. Addition holes need to be cut for the ball slot and the alignment holes.
- **Visual Criteria:** Simplistic box that allows decorations on the outside of the box and figurine placement outside the box. Not very clustered and each teammate can decorate a side of the box with their chosen design.
- **Interior Space:** Other than the three pillars around the center, there is plenty of space to wire the speakers and electronics inside the box.
- **Reliability:** If we can measure correctly the points to spread the three pillars evenly, there will be a good distribution of stress and force. Key factor would be the placement of the pillars; other things will be more or less trivial.
- **Cost:** Total cost of music box structure: $5.35
- **Material Properties:**

Top / Bottom Plywood Plate		Poplar Wood Pillars	
Elastic Module (N/m^2)	2000000000	Elastic Module (N/m^2)	2000000000
Poisons ratio (N/A)	0.394	Poisons ratio (N/A)	0.394
Density (kg / m^3)	690	Density (kg / m^3)	400

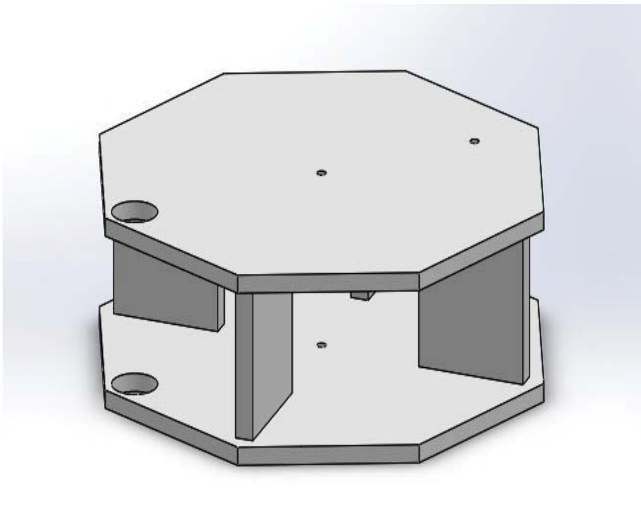
- **BOM:**

Item / Description	Size	Qty	Unit Price	Total price
Poplar Pillar	2" Diameter	1	$4.74/Foot	$4.74
Plywood Plates	30 cm	2	$0	$0
Flathead Nails	2"	6	$3.07/30 nails	$0.61

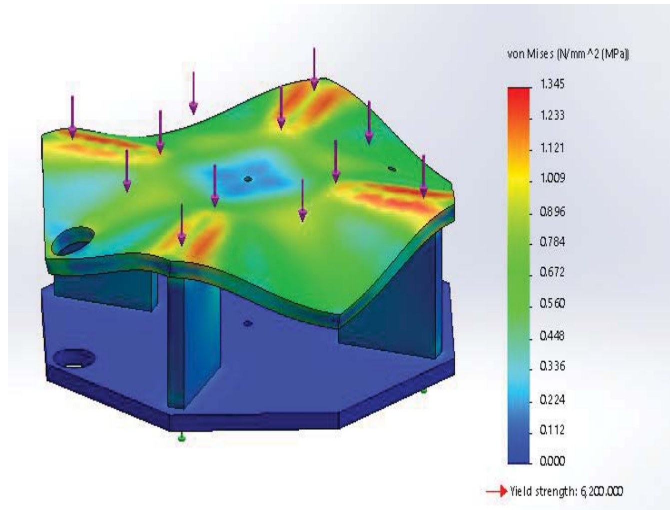
<u>Thomas Van's Structure Design</u>

Detailed Structure Design #3

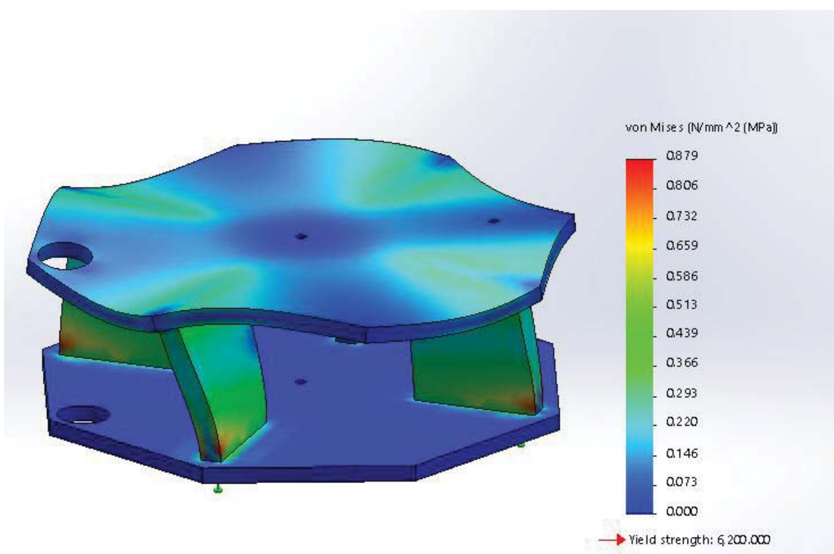
Model:



Vertical Load (800 N Test):



Torque Load (15 N.m Test):



Design #3 Specifications Details:

- **Weight:** 1.04 kg
- **Strength:**

Maximum Stress (MPa)	1.345
Maximum Displacement (mm)	0.1273
Maximum Displacement (mm) Due to Torque	0.05154

- **Ease of Manufacturing:** 4 rectangular wooden posts secured via wood screws.
- **Visual Criteria:** Symmetric and Clean.
- **Interior Space:** A lot of space. Can be varied by reducing post size
- **Reliability:** Sturdy (5 on 1-5 scale)
- **Material Properties:**

Top / Bottom Plywood Plate		Poplar Wood Pillars	
Elastic Module (N/m^2)	2000000000	Elastic Module (N/m^2)	2000000000
Poisons ratio (N/A)	0.394	Poisons ratio (N/A)	0.394
Density (kg / m^3)	690	Density (kg / m^3)	400

- **BOM:**

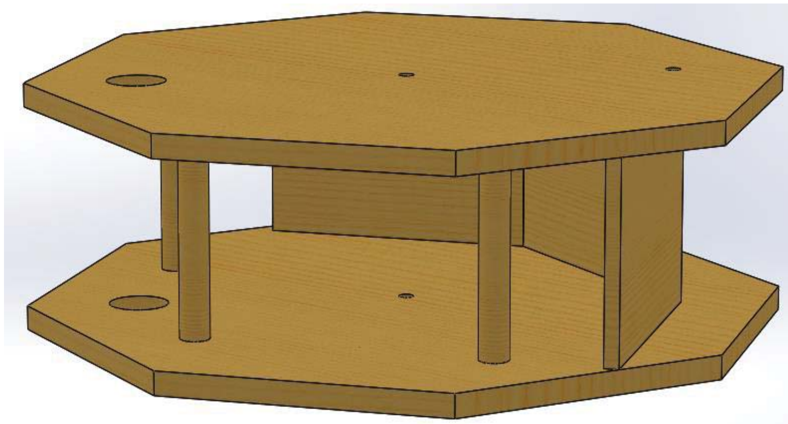
Item / Description	Size	Qty	Unit Price	Total price
Plywood	0.5 in thickness cut to size	1	$1.00	$1.00
Plywood Plates	12 in * 12in * (11/32)	2	$1.00	$2.00
Total Cost				$3.00

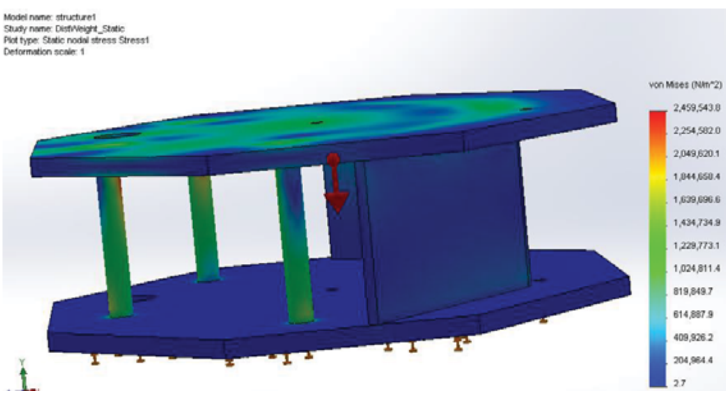
- **Cost:** Total cost of music box structure: $3.00

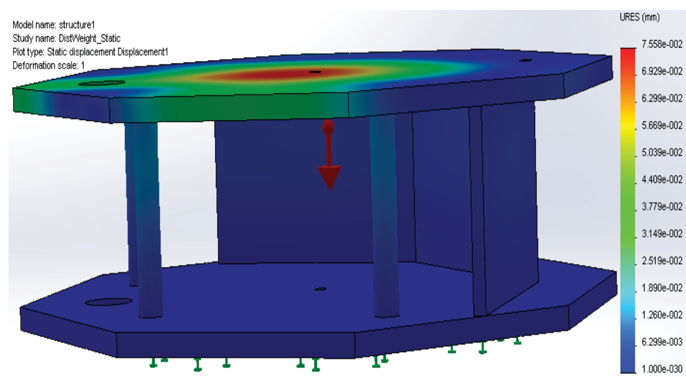
<u>Fady Barsoum's Structure Design</u>

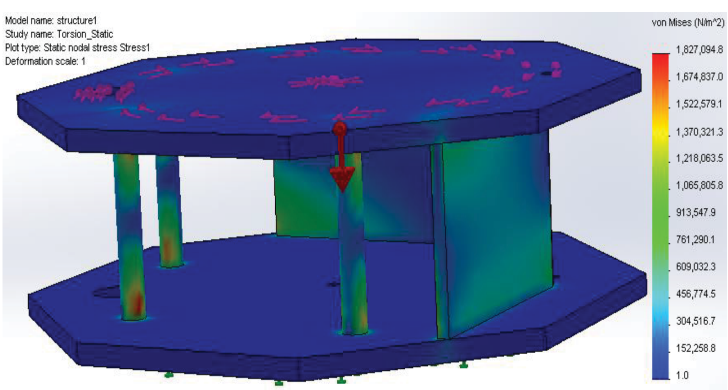
Detailed Structure Design # 4

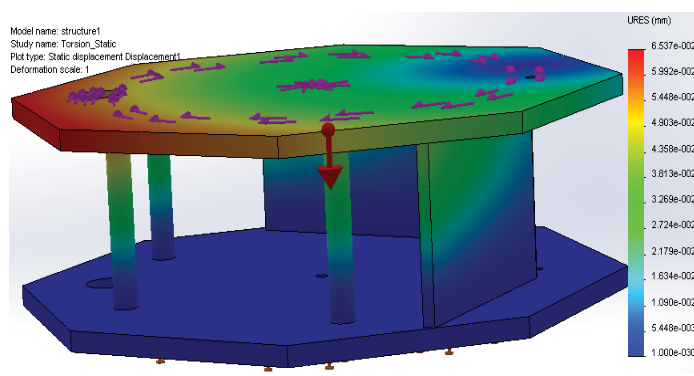
Images:











Design #4 Specifications Details:

- **Weight:** 0.81 kg
- **Strength:**

Maximum Stress (MPa)	2.46
Maximum Displacement (mm)	0.076
Maximum Displacement (mm) Due to Torque	0.065

- **Ease of Manufacturing:** Three posts and 3 wood panels
- **Visual Criteria:** Crowded, like a theater
- **Interior Space:** Less than most, access limited to one side
- **Reliability:** Sturdy (5 on 1-5 scale)
- **Material Properties:**

Top / Bottom Plywood Plate		Poplar Wood Pillars	
Elastic Module (N/m^2)	2000000000	Elastic Module (N/m^2)	2000000000
Poisons ratio (N/A)	0.394	Poisons ratio (N/A)	0.394
Density (kg / m^3)	690	Density (kg / m^3)	400

- **BOM:**

Item / Description	Size	Qty	Unit Price	Total price
Wooden Posts	0.5 in diameter	1	$0.33	$0.33
Plywood Plates	12 in * 12in * (11/32)	3	$1.00	$3.00
Total Cost				$3.33

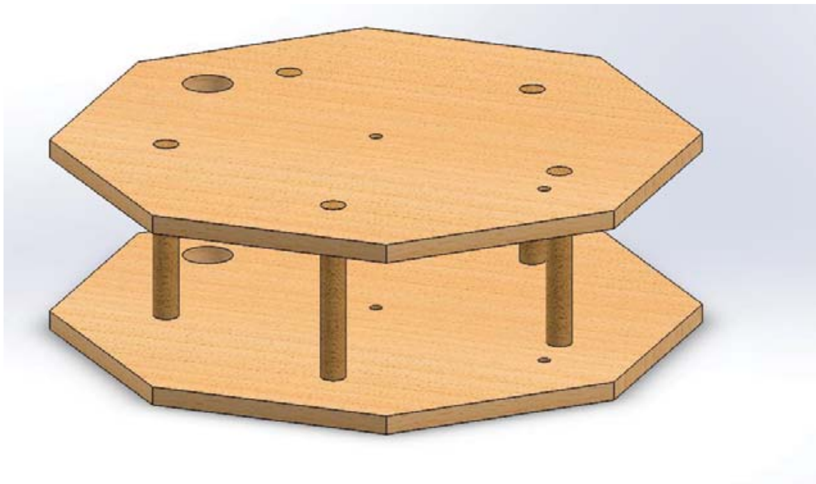
- **Cost:** Total cost of music box structure: $3.33

<u>Kushal Shah's Structure Design</u>

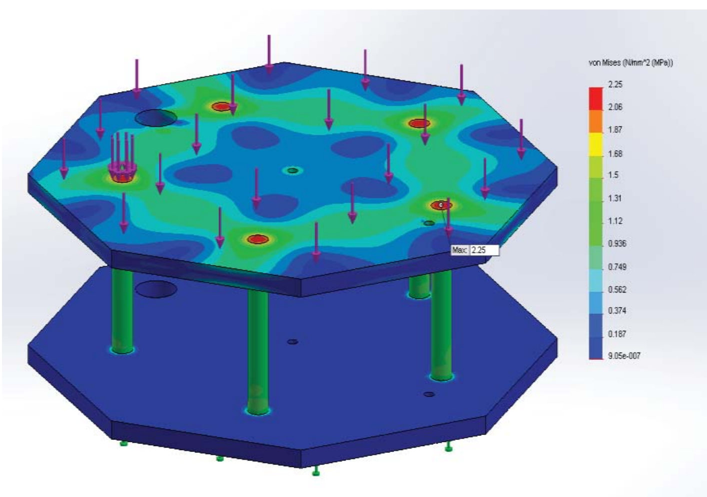
Detailed Structure Design # 5

Images:

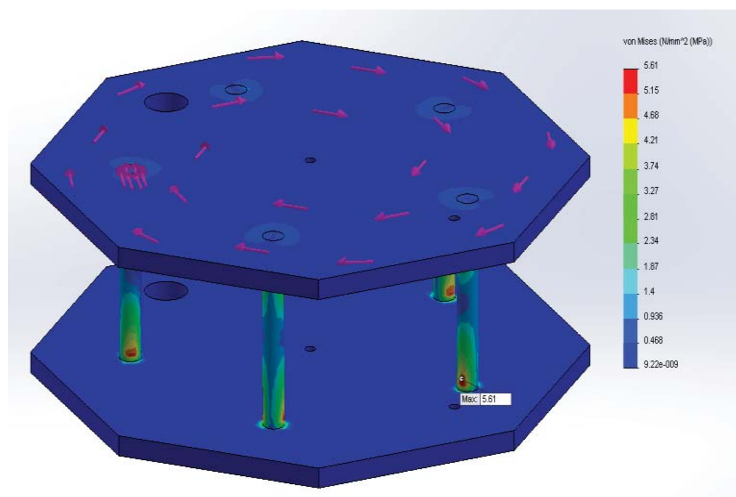
Model:



Vertical Load (800 N Test):



Torsional Load (800 N Test):



Design #5 Specifications Details:

- **Mass**: The box contains 0.83 kg
- **Strength**:

Maximum Stress (MPa)	5.61
Maximum Displacement (mm)	0.079
Maximum Displacement (mm) Due to Torsional Study	.260

- **Ease of Manufacturing**: Five Posts cuts and Wood Glue (Simple)
- **Visual Criteria**: Clean, spacious
- **Reliability**: Very Reliable. (Minimal Stresses)
- **Material Properties**:

Top / Bottom Plate		Wooden Post	
Elastic Module (MPa)	6200	Elastic Module (MPa)	8000
Compressive Strength (MPa)	10-24	Compressive Strength (MPa)	24
Poisons ratio (N/A)	0.22	Poisons ratio (N/A)	0.35
Density (kg / m^3)	500	Density (kg / m^3)	560

- **BOM**:

Item / Description	Size	Qty	Unit Price	Total price
Wood Posts (50cm or 20 in length)	0.5 in Diameter	1	$0.66	$0.66
Ply wood Plates	12 in * 12in * (11/32)	2	$1.00	$2.00
Total Cost				$2.66

Downselction

In order to justify why we chose a certain structure over the other four, we created a comparison chart and Pugh chart listing the structure strength, weight, manufacturing efficiency, space, cost, amplifying advantage shown below:

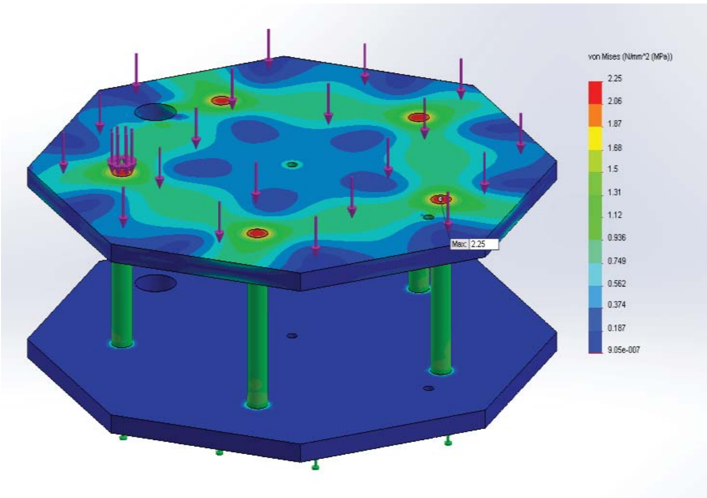
Comparison Chart For Down selection of the Structure						
Improtance		1	2	3	4	5
		Henry	Kushal	Thomas	Eric	Fady
1	Strength (Maximum Stess)	**2.372**	**2.25**	**1.345**	**1.6**	**2.46**
2	Weight	**0.79**	**0.82**	**1.04**	**2.4**	**0.81**
3	Cost	**$2.70**	**$2.66**	**$3**	**$5.35**	**$3.33**
4	Space (1 - 5) (5 is the best)	**5**	**4**	**3**	**2**	**3**
5	Manufacturing (Attachements)	**Wood Glue**	**Wood Glue**	**Wood Glues/ Screws**	**Nails / Wood Glue**	**Nails / Wood Glue**
5	Manufacturing (Cutting Parts)	**4 dowels**	**5 dowels**	**4 Squares**	**3 Big Posts**	**3 dowels + 3 Squares**
6	Amplifying Advantage (1-5)	**1**	**1**	**2**	**4**	**3**

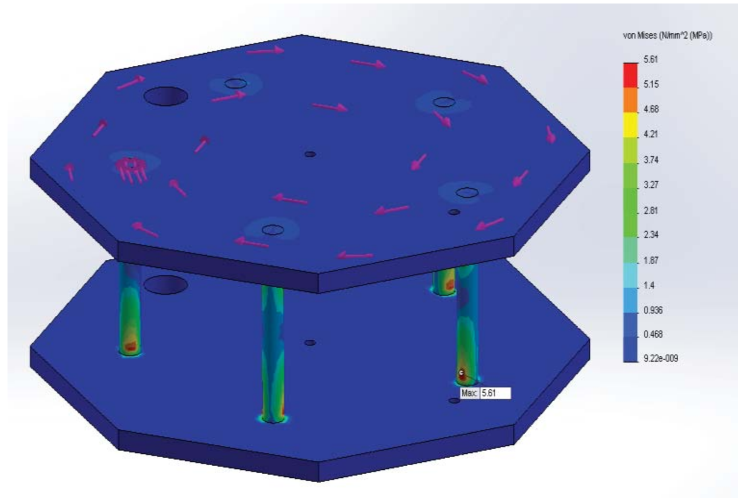
Pugh Concept Selection Chart Template						
Importance		DATUM	1	2	3	4
		Kushal	Henry	Thomas	Eric	Fady
1	Strength (Maximum Stess)	0	-1	1	1	1
2	Weight	0	1	-1	-1	-1
3	Manufacturing	0	0	-1	0	-1
4	Space	0	1	-1	-1	-1
5	Cost	0	-1	-1	-1	-1
6	Amplifying Advantage	0	0	1	1	1
	Σ+	+0	+2	+2	+2	+2
	Σ-	-0	-2	-4	-3	-4
	Σ	0	0	-2	-1	-2

Structure Design Justification:

Through this Pugh chart, we decided to go with Design 5 because his structure had a well distributed stress, buckling and displacement loading results from FEA studies. In addition, there was minimal torque for each of the dowel pins. Kushal's structure had a maximum tensile stress of 2.25 MPa with max 0.079mm displacement, a maximum torsion of 5.61 MPa with 0.260mm max displacement, and a tensile and torsion buckling max displacement of 10.8mm and 33.65mm, respectively. The total cost of his structure is $2.66 which is the cheapest out of the five structures to build. Also, it is easy to manufacture as it only uses glue to adhere the posts to the plates. The material used for the structure is made of plywood and hardwood dowel pins that were supplied by the instructor and was bought in bulk which reduced its price. In terms of interior space, there is plenty of space in the inside of the structure for the electronics and speaker to be placed inside. After finalization of the structural design of our music box, the CAD model was then printed out and the music box structural design was sent to the manufacturing stage.

Structure Design FEA Results:





FEA Result Summary:

After choosing the design, following results were obtained from the FEA for final concept design.

- The mass of the box: 0.83 kg
- Maximum Stress due to torsion (MPa): 5.61
- Maximum Stress due to compressive stress (MPa): 2.25
- Maximum Displacement (mm): 0.079
- Compressive Strength: 15 MPa
- Factor of Safety: 2.67
- Buckling Load Factor: 10

Structure Design BOM:

Item / Description	Size	Qty	Unit Price	Total price
Wood Posts (50cm or 20 in length)	0.5 in Diameter	1	$0.66	$0.66
Ply wood Plates	12 in * 12in * (11/32)	2	$1.00	$2.00
Total Cost				$2.66

SECTION 4: BALL RAMP / DETECTION / CATCH – RELEASE DESIGN CONCEPT

Music Box Detection, Catch and Release Concept Development Summary

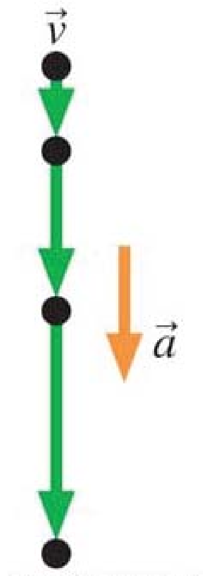
Goal: to develop the concept design for components needed to detect, catch, and release the ball

- ***Detection, "Catch and Release" Design Concept Process:***
  - Necessary specifications determined and discussed
  - Solutions brainstormed by group
  - Complete solution proposals/sketches developed by each group member
  - Separate components of each complete solution analyzed and compared
  - Performed down selection for each component and design was finalized

- Primary Components that were obtained for the final Design are:
  - Ball Ramp: Straight Down Polycarbonate Tube
  - Detection Method: Photoresist or and LED light.
  - Catch – Release Method: Servo
  - Joint Method: Wood Glue / Screws.

Ball Drop Kinematics Mathematical Model

- In order, to come up with logical design concepts, mathematical model of ball kinematics was devolved and it is presented below.



To find the velocity of the ball at given height:

$$(v_f^2) = (v_o^2) + 2a(h_f - h_o)$$

To find the time that ball takes to achieve its instantaneous velocity:

$$v_f = v_o + at$$

	Height at the trigger	Velocity at the trigger	Time at the Trigger	Height at the shutter	Velocity at the Shutter	Time at the Shutter	Delta Height	Respons e time (Delta t)
	h_t (cm)	V_t (m/s)	t_t (s)	h_s (cm)	V_s (m/s)	t_t (s)	Δh (cm)	Δt (s)
No Box Failure	3	0.77	0.0782	7	1.17	0.1195	4.0000	0.0413
1 box above failure	13	1.60	0.1629	17	1.83	0.1863	4.0000	0.0234
2 box above failure	23	2.12	0.2167	27	2.30	0.2347	4.0000	0.0181

- It can be seen from the table above that the ball travels with high velocity and the time period for catching the ball is very short. This short catching time should be considered in designing the ball drop.

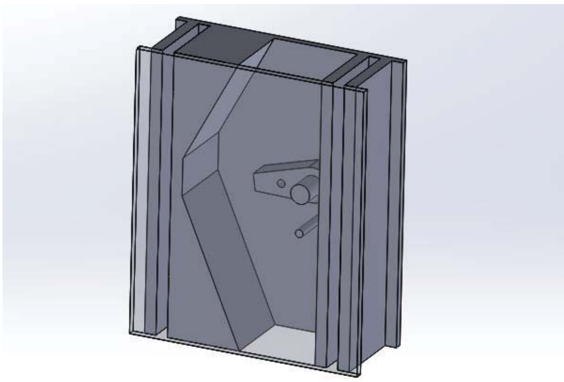
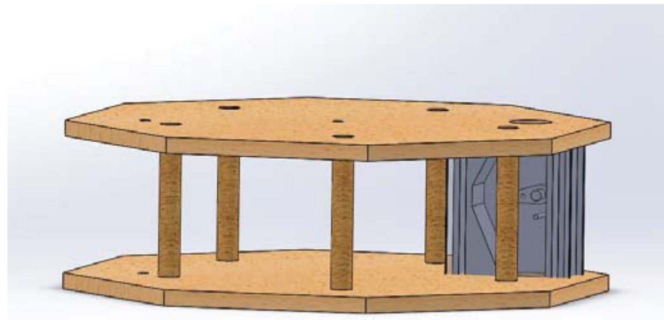
Detailed Design Concepts:

- Few design concepts were generated by the team and they are presented below.

Kushal Shah's Ball Sense Design:

Detailed Ball Sense Catch Design #1

Images:

Design #1 Specifications Details:

- **Detection Method**: Install Hall Effect sensor at the entrance
- **Catch Method**: Lever and spring
- **Release Method**: Lever and spring
- **Ease of Manufacturing**: Difficult but 3D printing may be easier
- **Visual Criteria/Ease Access:** Clean and adventurous but hard to get inside if it failed.
- **Reliability/Accuracy:** (3- being sometime it may fail early or late)
- **Power Consumption if possible:** (3.3 V and 0.2 amps for the hall effect sensor)

BOM:

Item / Descripion	Size	Qty	Unit Price	Total price
Two Acrylic Plate		1	~ $15	~ $15
Link		1	~ $2	~ $2
Glue		1	~ $2	~ $2
Pin		1	~$.50	~$.50
Spring		1	~$.25	~$.25
Total Cost				~$20

Total Cost: ~ $20

Thomas Van's Ball Sense Design:

Design #2 Specifications Details:

- **Detection Method**: Install Hall Effect sensor at the entrance
- **Catch Method**: Lever and spring
- **Release Method**: Lever and spring
- **Ease of Manufacturing**: Basic drilling.
- **Visual Criteria/Ease Access:** Simple and works well
- **Reliability/Accuracy:** No power consumed when off and acts as electronic fail safe. Easily adjustable for optimized and reliable stoppage.
- **Power Consumption if possible:** 0.75A @ 6V. No power consumed when off and acts as electronic fail safe. This is 4.5W. If it is operated for 2 seconds for every cycle, it would use 9 W-s per cyclle which is equal to 0.002500002 W-h. (3.3 V and 0.2 amps for the Hall Effect sensor). Roughly speaking, a 9V battery is a 500 mA-hour battery ad, can put out 500 mA for 1 hour so 9 volts x .5 amps = 4.5 watts for 1 hour. Probably less in real life. That's 4.5 watts for 3600 seconds. We use in 2 second intervals. That's 1800 cycles. According to this website, a 9 volt battery will store 580 mA hours. This means .58 amps at 9 volts for 1 hour which is 5.22 watt hours, or 18.8 KJ.

BOM:

Item / Description	Size	Qty	Unit Price	Total price
Medium Solenoid	.3 lb	1	$14.95	$14.95
Hall sensor		1	$1	$1
Total Cost	$15.95			

Total Cost: $15.95

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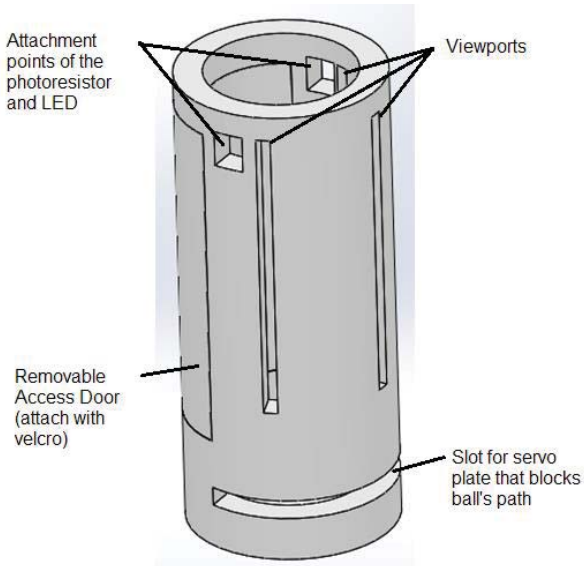
Fady Barsoum's Ball Sense Design:

Detailed Ball Sense Catch Design #3

Images:



Design #3 Specifications Details:

- **Detection Method**: Photo-resistor and LED
- **Catch Method**: Servo moves a plate into a slot in the pipe, blocking the path of the ball
- **Release Method**: Servo removes plate from underneath the ball
- **Ease of Manufacturing**: A bit of machining on a PVC pipe is all needed.
- **Visual Criteria/Ease Access:** Removable half of pipe to allow for access
- **Reliability/Accuracy:** (4- being sometime it may fail early or late)
- **Power Consumption if possible:** (3.3 V and 0.2 amps for the Hall Effect sensor). servo activated twice

BOM:

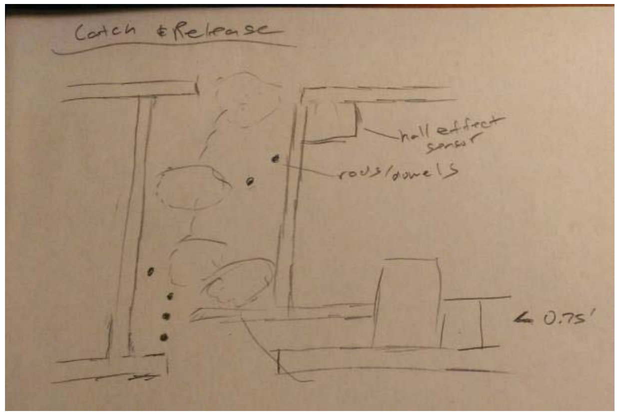
Item / Descripion	Size	Qty	Unit Price	Total price
PVC Pipe	ID: 1", OD: 1-3/8"	1	$1.67	$1.67
Sensor: Optical Detector / Phototransistor		1	$1.13	$1.13
LED		1	$0.27	$0.27
Micro Servo		1	$5.36	$5.36
Velcro		1	$0.62	$0.62
Total Cost				$9.05

Total Cost: $9.05

<u>Henry Diep's Ball Sense Design:</u>

Detailed Ball Sense Catch Design #4

Images:



Design #4 Specifications Details:

- **Detection Method**: Hall-effect sensor (one piece, easier, lighter, less hassle)
- **Catch Method**: Servo moves a plate into a slot in the pipe, blocking the path of the ball/ Obstructing dowel pins
- **Release Method**: Servo removes plate from underneath the ball
- **Ease of Manufacturing**: Just need to drill corresponding holes into polycarbonate. Could use machine shop mill to mill polycarbonate.
- **Visual Criteria/Ease Access:** Make it look wacky with punctured pins going through the pipe.
- **Reliability/Accuracy:** Good, strong pins to withstand the impact of the ball assuming the above box fails.
- **Power Consumption if possible:** (3.3 V and 0.2 amps for the Hall Effect sensor). servo activated twice. Power required to power hall + servo arm

BOM:

Item / Descripion	Size	Qty	Unit Price	Total price
Polycarbonate pipe	ID: 1 1/8'', OD: 1 ¼'' L: 1 ft	1	$3.98/ft	$3.98
Maple dowel rods (less dense than oak)	¼'' dia 36'' length	1	$0.90	0.90
Multi-fit foam sleeve	Dia 6''	1	$4.78	$4.78
Total Cost				9.66

Total Cost: $9.66

Downselction

- The preceding design concepts are complete solutions consisting of:
  1) The path of the ball
  2) Detection method
  3) Catch and release mechanism

- We broke down these detailed, complete design solutions down into their component parts, and for each component, we compared the solutions using an individual Pugh comparison chart.

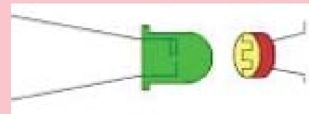
Ball Path Selection

	Concepts Summary Chart					
		1	2	3	4	5
	Concept	Straight Down (PVC)	Straight Down (Polycarbonate)	Dowel Pins (Polycarbonate)	Tube Path (Polycarbonate)	Springs Path
1	Chances of getting stuck	None	None	Low	Depends on angles but relatively high	Depends on angles but relatively high
2	Manufacturing	Cutting to length, creating viewports, creating entryway	Cutting to length, creating entryway	Cutting to length, a few drilled holes, creating entryway	Cutting to length and assembly	Cut paths out of wood, add springs and clear wall
3	Accessibility	Easy	Easy	Easy	Medium	Difficult
4	View of the ball	Tiny Viewports	Full	Full	Full	Can be full
5	Ball Arresting	None	None	A bit of hindrance	Very Slowed	Very Slowed
6	Cost	$1.67	$3.52	$3.66	$4+	<$1

	Pugh Concept Selection Chart					
		DATUM	1	2	3	4
		Straight Down (Polycarbonate)	Straight Down (PVC)	Dowel Pins (Polycarbonate)	Tube Path (Polycarbonate)	Springs Path
1	Chances of getting stuck	0	0	0	-1	-1
2	Manufacturing	0	-1	-1	1	-1
3	Accessibility	0	0	0	-1	-1
4	View of the ball	0	-1	0	0	-1
5	Ball Arrest	0	0	1	1	1
6	Cost	0	1	0	-1	1
	Σ	0	-1	0	-1	-2

We determined the Ball Path solution that best fits our criteria is the straight-down polycarbonate tube with dowel pins, as it is the most reliable, one of the easiest to manufacture, and costs the least, while providing easy access to and view of the ball.

Detection Method Selection

	Concept Summary Chart			
		1	2	3
				
Importance	Concept	Hall Effect Sensor	Snap Switch	Optical
1	Reliability	**Good**	**Fair (chance of ball getting stuck)**	**Good**
2	Ease of Manufacturing	**One component, 3 wires**	**One component, two wires**	**Two components, 4 wires**
3	Cost	**$0.95**	**$4.42**	**$1.40**

Importance	Pugh Concept Selection Chart			
		DATUM	1	2
		Optical	Snap Switch	Hall Effect
1	Reliability	0	**-1**	**0**
2	Ease of Manufacturing	0	**1**	**1**
3	Cost	0	**-1**	**1**
	Σ	0	-1	2

Therefore for the detection method, we determined the solution that best fits our criteria is the Hall Effect sensor, as it is the simplest to incorporate into our designs and, we believe, works as reliably as the Optical sensor at a lower cost. However, if we encounter any difficulties with it (as none of our group members have any prior experience working with a Hall Effect sensor) our next best option is the Optical sensor (photoresistor), which has more components and costs more, but is more reliable than the Snap Switch.

We later determined through research that the Hall Effect sensor is not as reliable at detecting a metal ball as we had initially thought it would be. This necessitated we switch to the Optical Sensor instead, as it was the next best option for our criteria.

Catch and Release Mechanism Selection

	Concept Summary Chart			
		1	2	3
				
Importance	Concept	Solenoid	Spring and Lever	Servo and Plank
1	Reliability	**Good**	**Inaccurate timing**	**Good**
2	Ease of Manufacturing	**Easy**	**Difficult**	**Easy**
3	Cost	**$15.27**	**<$5**	**$5.36**
4	Power Usage	**Bad**	**None**	**Ok**

	Pugh Concept Selection Chart			
Importance		DATUM	1	2
		Servo and Plank	Spring and Lever	Solenoid
1	Reliability	0	**-1**	**0**
2	Ease of Manufacturing	0	**-1**	**0**
3	Cost	0	**1**	**-1**
4	Power Consumption	0	**1**	**-1**
	Σ	0	0	-2

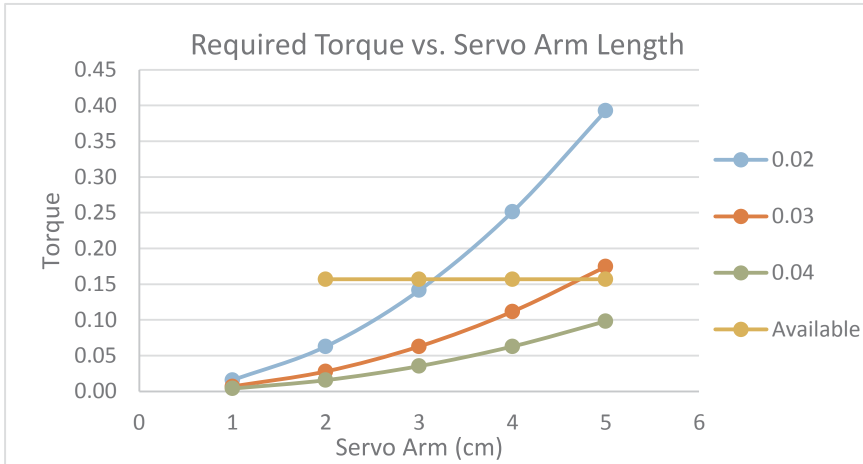
Both the “Servo and Plank” mechanism and the “spring and Lever” mechanism scored the highest on our chart. However, the “Servo and Plank” scored higher than the “spring and Lever” in the two most important criteria: Reliability and Ease of Manufacturing. Therefore the “Servo and Plank” was chosen as the solution that best fits our criteria.

With the concepts decided on, we next designed the electronics that will make each of the needed electronic components function properly:

Servo Speed Mathematical Model:

- To calculate required speed and the required electrical power and current were calculated using the equations below and values of time period to catch the ball from previous section. The graph shows the torque required for different target times and different servo arm lengths.

1. $Arc_{Length}\ (D_{travel}) = Radius\ (r) * Angle_{(Travel)}$
2. $V_{Velocity} = \frac{D_{Distance\,travel}}{t_{(time)}}$
3. $a_{acceleration} = \frac{(2*d)}{t^2}$
4. $F_{Force} = m_{mass} * a$
5. $T_{Torque} = F * r$
6. $P_{Mehcanical\ Required\ Power} = F * V$
7. $P_{Mehcanical} = P_{Electrical} = I_{current} * V_{Voltage}$
8. $I_{required} = \frac{P_{mechanical}}{V_{provided}}$



- To design different radius of the arm and the target time were varied and results were tabulated as shown below.

Target time	Radius of the arm(cm)	R arm (m)	Degree distance travel	Travel Distance (m)	Velocity (m/s)	Acceleration (m/s^2)	Force (N)	Torque Required (N-m)	Available Torque (N-m)	Mecahnical Power	Required Electrical Power	Required Current (Amps) at 5V	Required Current (mA) at 5V
0.01	1	0.01	90	0.016	1.571	314.16	6.28	0.06		9.87	9.87	1.97	1973.92
0.01	2	0.02	90	0.031	3.142	628.32	12.57	0.25	0.16	39.48	39.48	7.90	7895.68
0.01	3	0.03	90	0.047	4.712	942.48	18.85	0.57	0.16	88.83	88.83	17.77	17765.29
0.01	4	0.04	90	0.063	6.283	1256.64	25.13	1.01	0.16	157.91	157.91	31.58	31582.73
0.01	5	0.05	90	0.079	7.854	1570.80	31.42	1.57	0.16	246.74	246.74	49.35	49348.02
0.02	1	0.01	90	0.016	0.785	78.54	1.57	0.02	0.16	1.23	1.23	0.25	246.74
0.02	2	0.02	90	0.031	1.571	157.08	3.14	0.06	0.16	4.93	4.93	0.99	986.96
0.02	3	0.03	90	0.047	2.356	235.62	4.71	0.14	0.16	11.10	11.10	2.22	2220.66
0.02	4	0.04	90	0.063	3.142	314.16	6.28	0.25	0.16	19.74	19.74	3.95	3947.84
0.02	5	0.05	90	0.079	3.927	392.70	7.85	0.39	0.16	30.84	30.84	6.17	6168.50
0.03	1	0.01	90	0.016	0.524	34.91	0.70	0.01	0.16	0.37	0.37	0.07	73.11
0.03	2	0.02	90	0.031	1.047	69.81	1.40	0.03	0.16	1.46	1.46	0.29	292.43
0.03	3	0.03	90	0.047	1.571	104.72	2.09	0.06	0.16	3.29	3.29	0.66	657.97
0.03	4	0.04	90	0.063	2.094	139.63	2.79	0.11	0.16	5.85	5.85	1.17	1169.73
0.03	5	0.05	90	0.079	2.618	174.53	3.49	0.17	0.16	9.14	9.14	1.83	1827.70
0.04	1	0.01	90	0.016	0.393	19.63	0.39	0.00	0.16	0.15	0.15	0.03	30.84
0.04	2	0.02	90	0.031	0.785	39.27	0.79	0.02	0.16	0.62	0.62	0.12	123.37
0.04	3	0.03	90	0.047	1.178	58.90	1.18	0.04	0.16	1.39	1.39	0.28	277.58
0.04	4	0.04	90	0.063	1.571	78.54	1.57	0.06	0.16	2.47	2.47	0.49	493.48
0.04	5	0.05	90	0.079	1.963	98.17	1.96	0.10	0.16	3.86	3.86	0.77	771.06

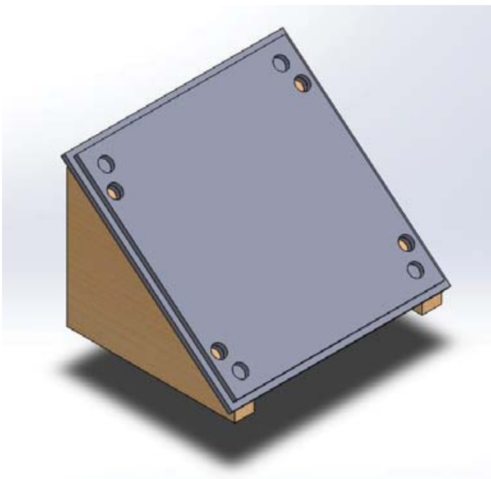
SECTION 5: THEME / SPEAKER / ELECTRONIC ENCLOSURE/ SOUND PRODUCTION DESIGN CONCEPT

Theme Design Concept:

- The theme was obtained from the survey. This was done so we can sell out box to most of the customers.
- The Theme was chosen to be Lion King.
- We will have figurines and we will paint top blue and bottom green.

Speaker Design Concept:

- The given speaker was used
- The design for the structure was as a rock to match our theme design.
- The speaker mount was designed for the speaker to lie slanted in the music box.
- We decided not to make the speaker mount horizontal because we wanted to give the speaker mount enough room to allow it to be removed easily from the music box if needed.
- The speaker mount will be attached with Velcro so any internal malfunctions or issues can easily be solved by removing the speaker mount.



Arduino Enclosure Design Concept:

- The enclosure was design with the usability in mind.
- The design allows to program the box easily with the port availability on its front end.
- We decided to have the opening on the top so the battery can be replaced.
- In addition, this panel will have the battery holder and the switches so the energy can be saved when the box is not used.
- We also decided to make the Arduino and the shield Holder.
- The holes will drilled to run the wires around in the box.

Sound Production Design Concept:

Concept 1: From Arduino

- Not actual instrument sound.

Concept 2: From Arduino + MIDI Shield

- Allows to play many different music.

Concept 3: Arduino play a prerecorded sound file stored on an MP3-type player

- Takes up lot of memory.

Down Selection

	Concept Summary Chart			
		1	2	3
Importance	Concept	Arduino - Wave	Arduino + MIDI Shield	Prerecorded Sound Via Arduino
1	Sound Quality (1 – 5)	3	5	4
2	Cost	~ $20	~ $40	~$25
3	Ease of Programming (Memory Usage and Debugging) (1-5)	3	5	4
4	Power Consumption (1-5)	4	3	4

	Pugh Concept Selection Chart			
Importance		DATUM	1	2
		Arduino - Wave	Prerecorded Sound Via Arduino	Arduino + MIDI Shield
1	Sound Quality (1 – 5)	0	+1	+1
2	Cost	0	0	-1
3	Ease of Programming (Memory Usage and Debugging) (1-5)	0	-1	+1
4	Power Consumption (1-5)	0	0	-1
	Σ	0	0	0

- From this chart, we decided to produce the sound from the MIDI shield because it will produce clear sound and it will allow the user to construct desired music for later time.

SECTION 6: MUSIC ASSIGNMENT DESIGN FOR PROGRAMMING

Developing Music Notes:

- The Music Instrument Shield was used in the music box. Following sheet specifications were obtained for music design. From these sheets, desired music can be produced.
  1) MIDI Chart for Instruments(Obtained from Music Instrument Shield Website)

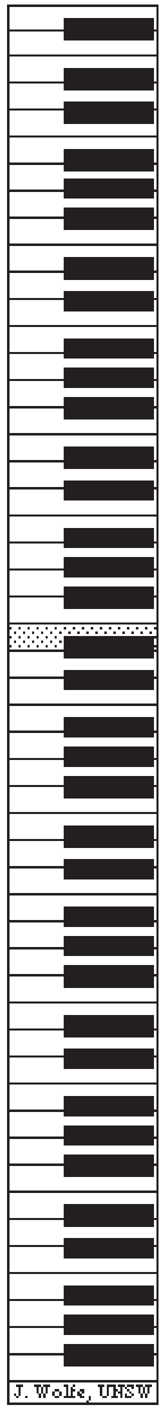
VS1053b Melodic Instruments (GM1)			
1 Acoustic Grand Piano	33 Acoustic Bass	65 Soprano Sax	97 Rain (FX 1)
2 Bright Acoustic Piano	34 Electric Bass (finger)	66 Alto Sax	98 Sound Track (FX 2)
3 Electric Grand Piano	35 Electric Bass (pick)	67 Tenor Sax	99 Crystal (FX 3)
4 Honky-tonk Piano	36 Fretless Bass	68 Baritone Sax	100 Atmosphere (FX 4)
5 Electric Piano 1	37 Slap Bass 1	69 Oboe	101 Brightness (FX 5)
6 Electric Piano 2	38 Slap Bass 2	70 English Horn	102 Goblins (FX 6)
7 Harpsichord	39 Synth Bass 1	71 Bassoon	103 Echoes (FX 7)
8 Clavi	40 Synth Bass 2	72 Clarinet	104 Sci-fi (FX 8)
9 Celesta	41 Violin	73 Piccolo	105 Sitar
10 Glockenspiel	42 Viola	74 Flute	106 Banjo
11 Music Box	43 Cello	75 Recorder	107 Shamisen
12 Vibraphone	44 Contrabass	76 Pan Flute	108 Koto
13 Marimba	45 Tremolo Strings	77 Blown Bottle	109 Kalimba
14 Xylophone	46 Pizzicato Strings	78 Shakuhachi	110 Bag Pipe
15 Tubular Bells	47 Orchestral Harp	79 Whistle	111 Fiddle
16 Dulcimer	48 Timpani	80 Ocarina	112 Shanai
17 Drawbar Organ	49 String Ensembles 1	81 Square Lead (Lead 1)	113 Tinkle Bell
18 Percussive Organ	50 String Ensembles 2	82 Saw Lead (Lead)	114 Agogo
19 Rock Organ	51 Synth Strings 1	83 Calliope Lead (Lead 3)	115 Pitched Percussion
20 Church Organ	52 Synth Strings 2	84 Chiff Lead (Lead 4)	116 Woodblock
21 Reed Organ	53 Choir Aahs	85 Charang Lead (Lead 5)	117 Taiko Drum
22 Accordion	54 Voice Oohs	86 Voice Lead (Lead 6)	118 Melodic Tom
23 Harmonica	55 Synth Voice	87 Fifths Lead (Lead 7)	119 Synth Drum
24 Tango Accordion	56 Orchestra Hit	88 Bass + Lead (Lead 8)	120 Reverse Cymbal
25 Acoustic Guitar (nylon)	57 Trumpet	89 New Age (Pad 1)	121 Guitar Fret Noise
26 Acoustic Guitar (steel)	58 Trombone	90 Warm Pad (Pad 2)	122 Breath Noise
27 Electric Guitar (jazz)	59 Tuba	91 Polysynth (Pad 3)	123 Seashore
28 Electric Guitar (clean)	60 Muted Trumpet	92 Choir (Pad 4)	124 Bird Tweet
29 Electric Guitar (muted)	61 French Horn	93 Bowed (Pad 5)	125 Telephone Ring
30 Overdriven Guitar	62 Brass Section	94 Metallic (Pad 6)	126 Helicopter
31 Distortion Guitar	63 Synth Brass 1	95 Halo (Pad 7)	127 Applause
32 Guitar Harmonics	64 Synth Brass 2	96 Sweep (Pad 8)	128 Gunshot

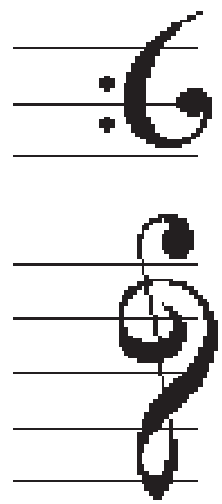
VS1053b Percussion Instruments (GM1+GM2)			
27 High Q	43 High Floor Tom	59 Ride Cymbal 2	75 Claves
28 Slap	44 Pedal Hi-hat [EXC 1]	60 High Bongo	76 Hi Wood Block
29 Scratch Push [EXC 7]	45 Low Tom	61 Low Bongo	77 Low Wood Block
30 Scratch Pull [EXC 7]	46 Open Hi-hat [EXC 1]	62 Mute Hi Conga	78 Mute Cuica [EXC 4]
31 Sticks	47 Low-Mid Tom	63 Open Hi Conga	79 Open Cuica [EXC 4]
32 Square Click	48 High Mid Tom	64 Low Conga	80 Mute Triangle [EXC 5]
33 Metronome Click	49 Crash Cymbal 1	65 High Timbale	81 Open Triangle [EXC 5]
34 Metronome Bell	50 High Tom	66 Low Timbale	82 Shaker
35 Acoustic Bass Drum	51 Ride Cymbal 1	67 High Agogo	83 Jingle bell
36 Bass Drum 1	52 Chinese Cymbal	68 Low Agogo	84 Bell tree
37 Side Stick	53 Ride Bell	69 Cabasa	85 Castanets
38 Acoustic Snare	54 Tambourine	70 Maracas	86 Mute Surdo [EXC 6]
39 Hand Clap	55 Splash Cymbal	71 Short Whistle [EXC 2]	87 Open Surdo [EXC 6]
40 Electric Snare	56 Cowbell	72 Long Whistle [EXC 2]	
41 Low Floor Tom	57 Crash Cymbal 2	73 Short Guiro [EXC 3]	
42 Closed Hi-hat [EXC 1]	58 Vibra-slap	74 Long Guiro [EXC 3]	

2) Note Chart for MIDI (Obtained from Google)

MIDI number	Note name	Frequency Hz	Period ms
21	A0	27.500	36.36
22		29.135	34.32
23	B0	30.868	32.40
24	C1	32.703	30.58
25		34.648	28.86
26	D1	36.708	27.24
27		38.891	25.71
28	E1	41.203	24.27
29	F1	43.654	22.91
30		46.249	21.62
31	G1	48.999	20.41
32		51.913	19.26
33	A1	55.000	18.18
34		58.270	17.16
35	B1	61.735	16.20
36	C2	65.406	15.29
37		69.296	14.29
38	D2	73.416	13.62
39		77.782	12.86
40	E2	82.407	12.13
41	F2	87.307	11.45
42		92.499	10.81
43	G2	97.999	10.20
44		103.83	9.631
45	A2	110.00	9.091
46		116.54	8.581
47	B2	123.47	8.099
48	C3	130.81	7.645
49		138.59	7.216
50	D3	146.83	6.811
51		155.56	6.428
52	E3	164.81	6.068
53	F3	174.61	5.727
54		185.00	5.405
55	G3	196.00	5.102
56		207.65	4.816
57	A3	220.00	4.545
58		233.08	4.290
59	B3	246.94	4.050
60	**C4**	**261.63**	**3.822**
61		277.18	3.608
62	D4	293.67	3.405
63		311.13	3.214
64	E4	329.63	3.034
65	F4	349.23	2.863
66		369.99	2.703
67	G4	392.00	2.551
68		415.30	2.408
69	**A4**	**440.00**	**2.273**
70		466.16	2.145
71	B4	493.88	2.025
72	C5	523.25	1.910
73		554.37	1.804
74	D5	587.33	1.703
75		622.25	1.607
76	E5	659.26	1.517
77	F5	698.46	1.432
78		739.99	1.351
79	G5	783.99	1.276
80		830.61	1.204
81	A5	880.00	1.136
82		932.33	1.073
83	B5	987.77	1.012
84	C6	1046.5	0.9556
85		1108.7	0.9020
86	D6	1174.7	0.8513
87		1244.5	0.8034
88	E6	1318.5	0.7584
89	F6	1396.9	0.7159
90		1480.0	0.6757
91	G6	1568.0	0.6378
92		1661.2	0.6020
93	A6	1760.0	0.5682
94		1864.7	0.5363
95	B6	1975.5	0.5062
96	C7	2093.0	0.4778
97		2217.5	0.4510
98	D7	2349.3	0.4257
99		2489.0	0.4018
100	E7	2637.0	0.3792
101	F7	2793.0	0.3580
102		2960.0	0.3378
103	G7	3136.0	0.3189
104		3322.4	0.3010
105	A7	3520.0	0.2841
106		3729.3	0.2681
107	B7	3951.1	0.2531
108	C8	4186.0	0.2389

Keyboard





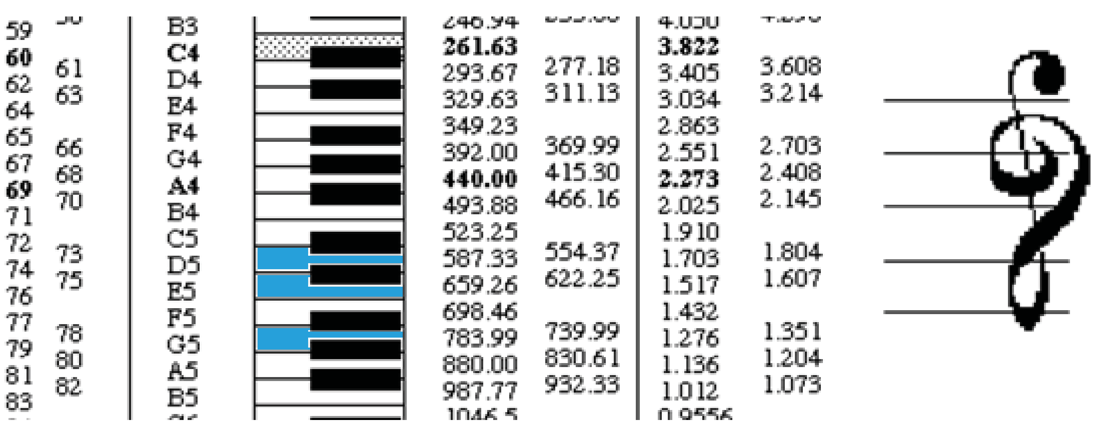
Development of Notes Assigned to Group:

1) Obtained Assigned notes for grand piano:

2) Related these notes and obtained its letter names:

- **Notes Assigned to Group Lion King is: D_5, G_5, E_5**

3) Determining the MIDI Notes Numbers:



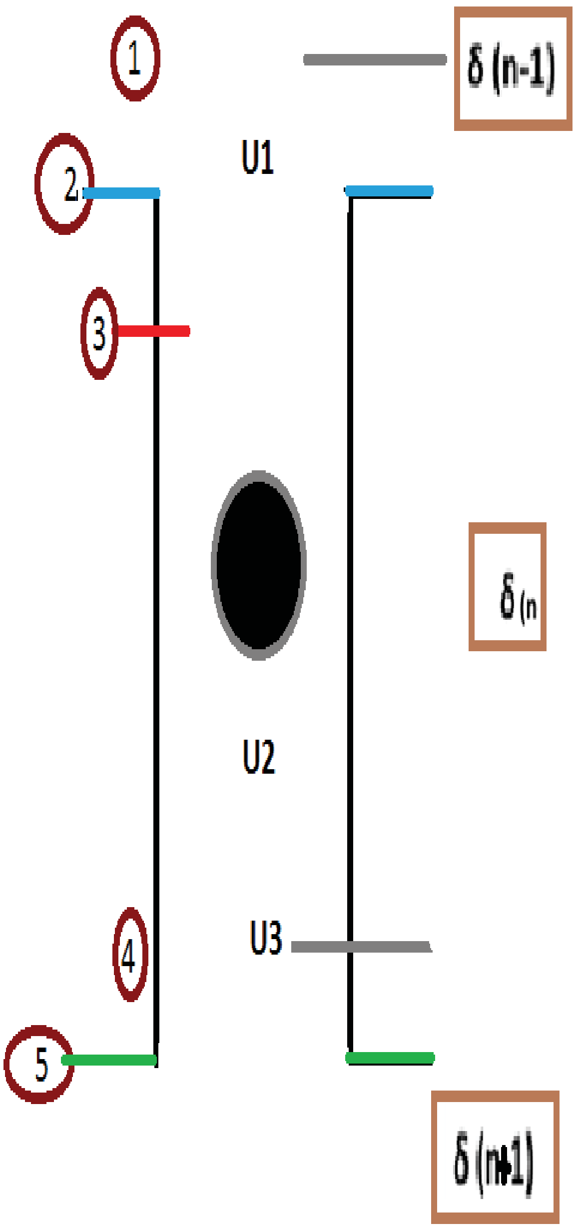
59		B3	246.94		4.050	
60	61	**C4**	**261.63**	277.18	**3.822**	3.608
62	63	D4	293.67	311.13	3.405	3.214
64		E4	329.63		3.034	
65	66	F4	349.23	369.99	2.863	2.703
67	68	G4	392.00	415.30	2.551	2.408
69	70	**A4**	**440.00**	466.16	**2.273**	2.145
71		B4	493.88		2.025	
72	73	C5	523.25	554.37	1.910	1.804
74	75	D5	587.33	622.25	1.703	1.607
76		E5	659.26		1.517	
77	78	F5	698.46	739.99	1.432	1.351
79	80	G5	783.99	830.61	1.276	1.204
81	82	A5	880.00	932.33	1.136	1.073
83		B5	987.77		1.012	
			1046.5		0.9556	

- **MIDI Note Numbers Assigned to Group Lion King is: 74** (0.5 Sec)**, 79** (0.5 Sec)**, 76** (1 Sec).

SECTION 7: TIMING CONCEPT

Analytical Model for Timing

- The timing is represented by two 2-second windows staggered by 0.5 seconds
  - One window is from the time when the ball enters the box and leaves the box – 2 second
  - Second Window is from the time music begins and stops. – 2 Second



- Assuming , → $u_1 = 0$
- Basic Kinematic Equation:

$$\Delta x = ut + \frac{1}{2}a\Delta t^2 \text{.......... (1)}$$

Using (1), time it takes from $Box_{\delta_{n-1}}$ to Boxδ.

$$t_2 = \delta_{n-1} = \sqrt{\frac{2(\Delta h_{1-2})}{g}}$$

$$u_2 = \frac{h_{1\to 2}}{\delta_{n-1}}$$

$$t_3 = t_{2\to 3} = Should\ be\ minimal$$

$$\boldsymbol{t_4 = t_{2\to 4} < (0.5 - \delta_{n-1} - t_3)}$$

- The time to start playing the music, t_s (Time of Delay in Programming)

$$\boldsymbol{t_s = 0.5 - \delta_{n-1} - t_3}$$

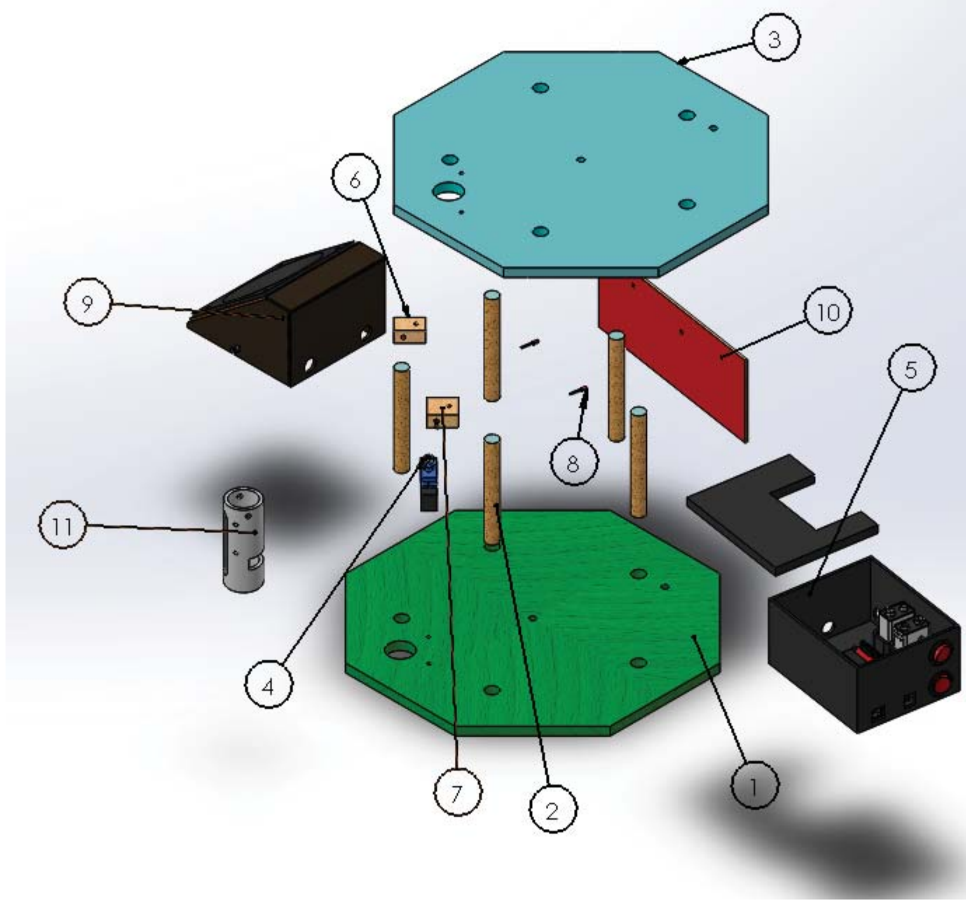
$$u_3 = 0$$

$$\delta_n = \sqrt{\frac{2(h_{4\to 5})}{g}}$$

SECTION 8: COMPLETE CONCEPT DESIGN (BOM)

Rough BOM of Concept Design

- In this section, rough BOM of the concept design is presented. The final model drawings are presented in the final section of the binder.



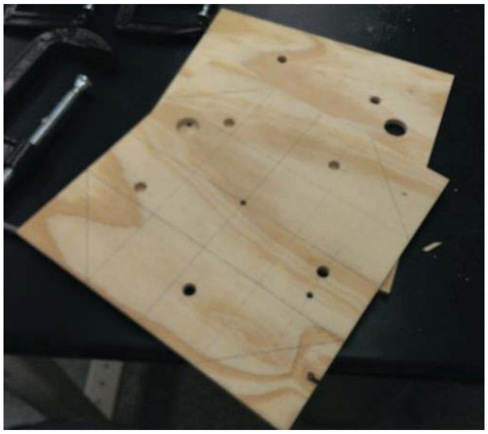
ITEM NO.	PART NUMBER	QTY.
1	Bottom Plate	1
2	Wooden Post	5
3	Top Plate	1
4	Servo	1
5	Electronic Enclosure	1
6	LED Holder	1
7	Photo Resistor Holder	1
8	LEDs	2
9	Speaker Assembly	1
10	Display Panel	1
11	Pipe	1

PHASE 2: PROTOTYPE DEVELOPMENT

SECTION 1: STRUCTURE FABRICATION

Fabrication of Prototype Structure:

- Following steps were taken to fabricate the structure prototype:
  1) Dimensioned the two top and bottom plywood plates from the center alignment hole
     a. In addition, dimensioning from the center point also allows the structure to be more reliable since the outer dimensions are less important and are trivial compared to the two alignment pins and pipe hole.



  2) Clamp and drill both plywood plates together to ensure they match together

  3) Cut the sides of square plate to obtain the octagon shape
  4) Cut down dowel pins to correct lengths and chamfer both sides for easy fitting into top and bottom plywood plates
  5) Glue and assemble plates as one whole piece to ensure proper connections between top and

bottom plywood plates

Finished Structure Design Isometric View

6) The top plate of the box is painted like the sky to fit our theme of the Lion King while the bottom plate is painted like the grass and the dowels represent the trees.

Colored Structure

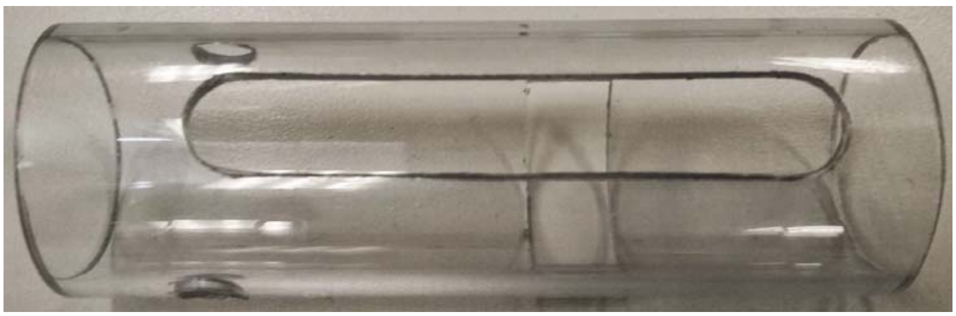
Post-Structure Analysis:

The top and bottom structure is octagon shaped and is composed of plywood. The 5 hardwood dowel pins are glued onto the base only so that the top can be removed to allow accessibility of the inside area where the electronics are to be placed. The overall dimensions of the music box structure are 10cm tall, 30cm long and 30cm wide. The pipe whole diameter is 1inch and the alignment pins are both 0.25inches in diameter. The weight of the box is 0.85kg and should be able to hold a maximum stress load of 2.25MPa with a 0.079mm displacement. The amount of torsion stress load it can have is 5.61MPa with a 0.260mm displacement. The music box has been tested to be able to align properly with other music boxes properly without issues. There weren't any complications with the manufacturing of the music box structure as the music box is designed to be simplistic but reliable and efficient.

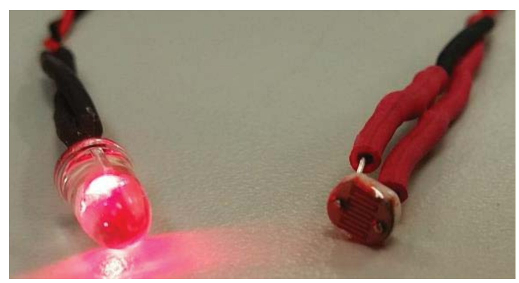
SECTION 2: BALL RAMP / DETECTION / CATCH - RELEASE FABRICATION

Initial Fabrication of Prototype Ball Detection, Catch and Release

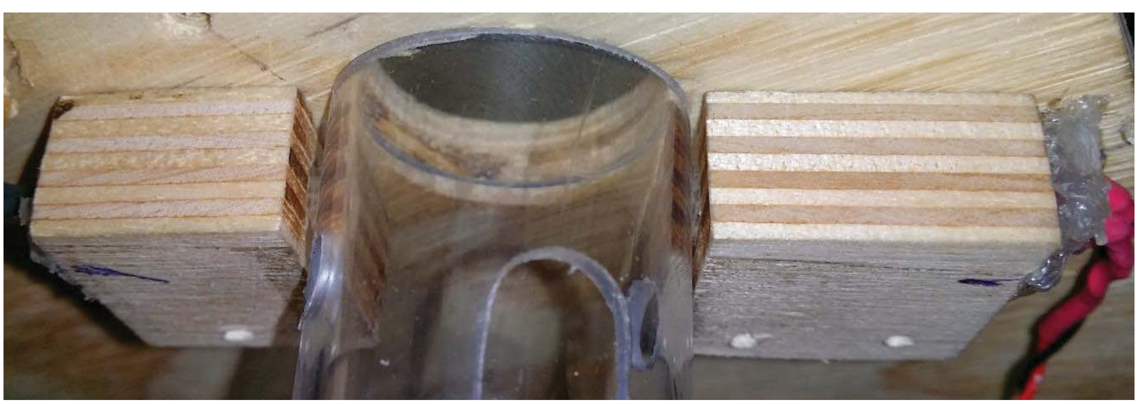
- Ball Path
    1) Polycarbonate tube cut down to the needed length (8cm)
    2) Tube dimensioned and holes and slots dimensioned from the bottom edge
    3) Holes and slots machined into the tube
    4) Later testing revealed the servo occasionally did not catch the ball so a rod was added against which the ball would hit to slow it down



- Ball Detection
    1) Photoresistor and LEDs purchased
    2) Different LEDs tested for brightness (red chosen as best detected)
    3) Leads soldered to both components
    4) Wooden mounting structures for the LED and photoresistor manufactured and mounted on the Music Box structure

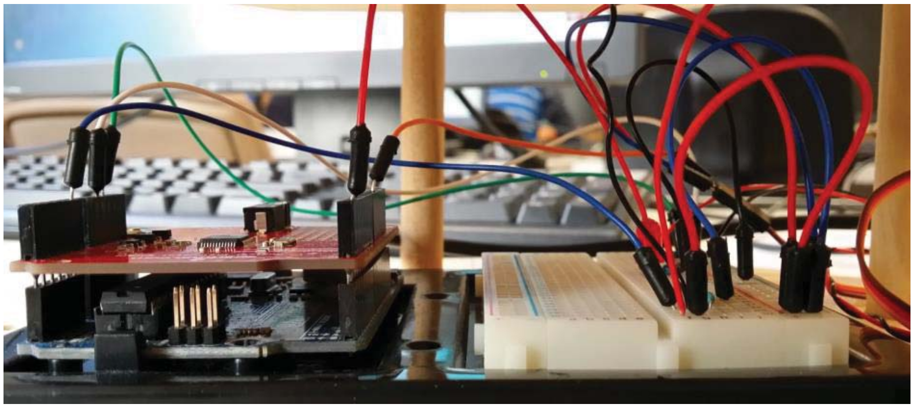


    5) Created electronic circuit to utilize the LED and photoresistor, and Arduino coded



- Ball Catch and Release
  1) Added an extension to the lever arm attached to servo
  2) Wooden mounting structures for servo manufactured and mounted on Music Box structure
  3) Servo connected with electronics to the Arduino and code developed for the servo to function
  4) The LED mount, servo mount, and photo sensor mount are made into block shapes because we wanted to use simple but solid shapes to hold our internal pieces together. Both of the blocks for each of the mounts are the same size to give a uniform symmetrical look to our music box. In addition, the blocks are large enough that they won't crack or break from screwing but small enough to not clutter up the internal music box space.

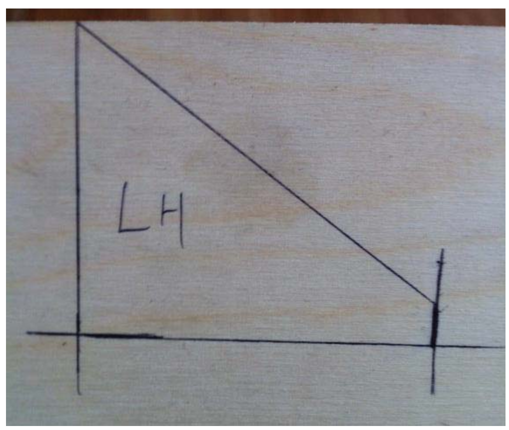
- Electronics
  1) Following the schematics in the design section, we wired the components and tested them
  2) Adjusted resistor values based on sensitivity requirements through trial and error



SECTION 3: SPEAKER BOX / ARDUINO BOX FABRICATION

Initial Fabrication and Prototype of Speaker Box and Arduino Box

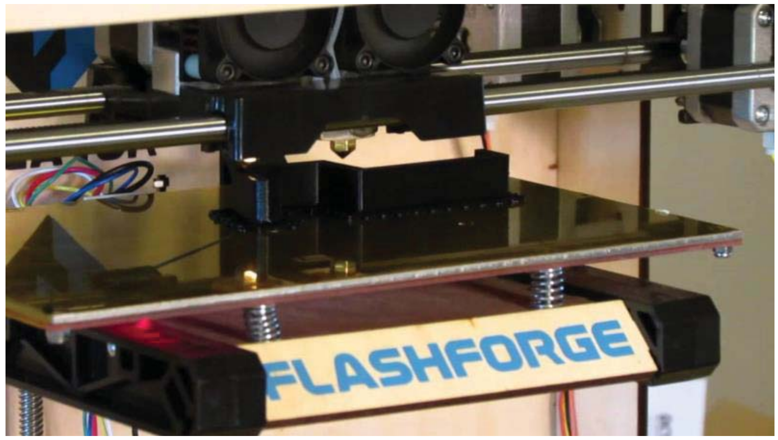
- Speaker Box
    1) Speaker box end plates are to be created from 3/8" wood. Speaker holder and box cover is to be constructed from 1/8" fiberboard. Everything will be assembled with screws
    2) First, we draw appropriate cut marks and drill marks on the material as noted on the engineering drawings.
        - Side pieces are taped together and cut at the same time to ensure symmetry.
        - Holes to line up with top were sketched with both plates still together to ensure they were drilled at the same area.



    3) Cut wood and fiberboard on band saw and drill marked holes.

4) Assemble with screws and mount electronic components such as speaker and potentiometer. Guide wires through holes.
5) Paint the speaker box when finished.

- Arduino box
    1) The main portion of the Arduino box is plastic. After being drawn on SolidWorks, it is sent to the 3D printer for rapid manufacturing.



2) After verifying that the box is to spec, we install the Arduino and two 9V batteries.
3) The top cover of the music box is made out of wood. We draw the dimensions on the wood and cut it.

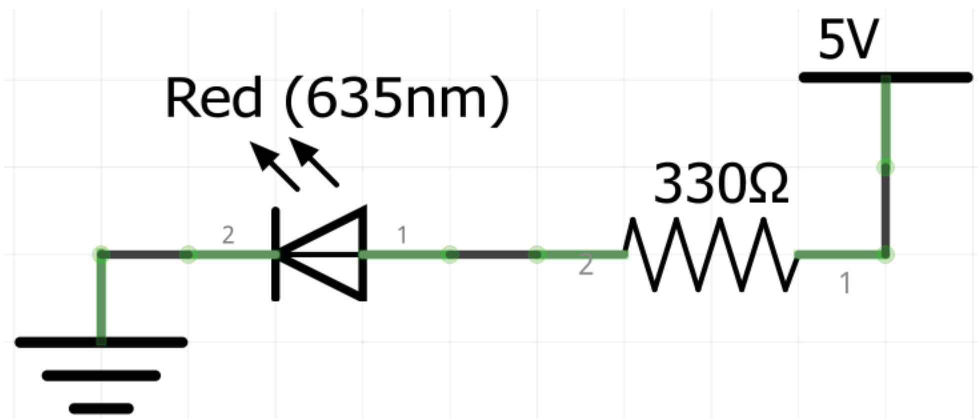
Top cover is then painted and attached to the Arduino via Velco strips.

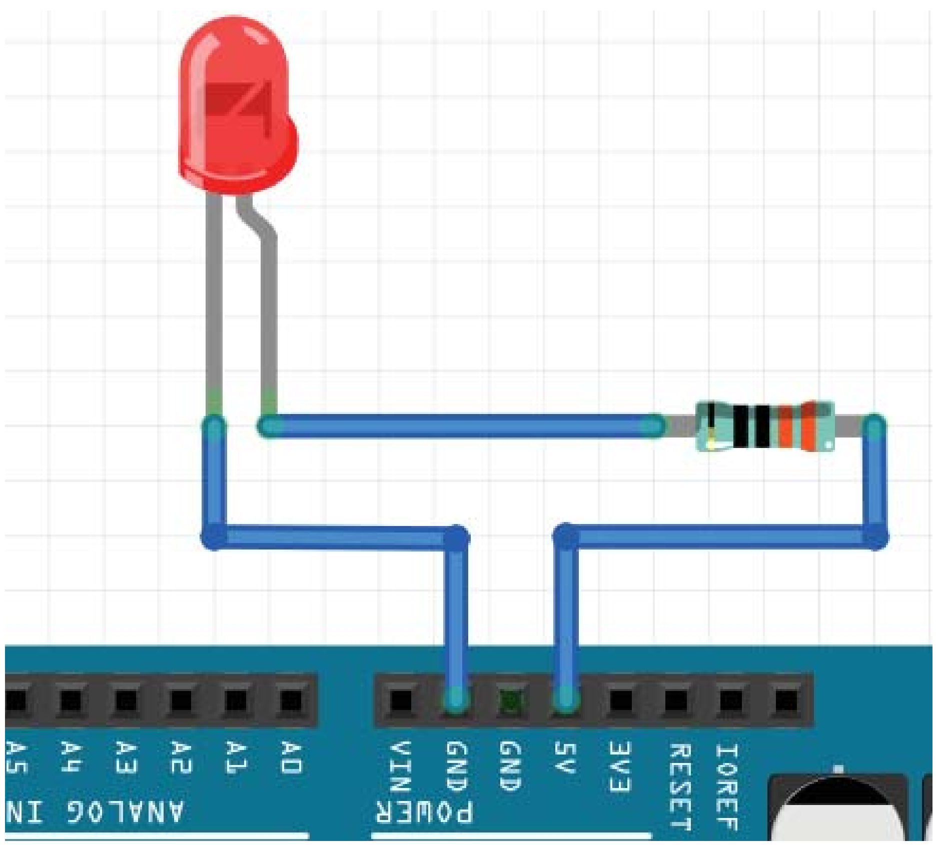
SECTION 4: WIRING DIAGRAM

The following are the electronic schematics and diagrams developed to make the electronic components in the Detection, Catch, and Release aspect of the Music Box function properly. (Arduino shown but actual connection is done through a solder- or bread- board)

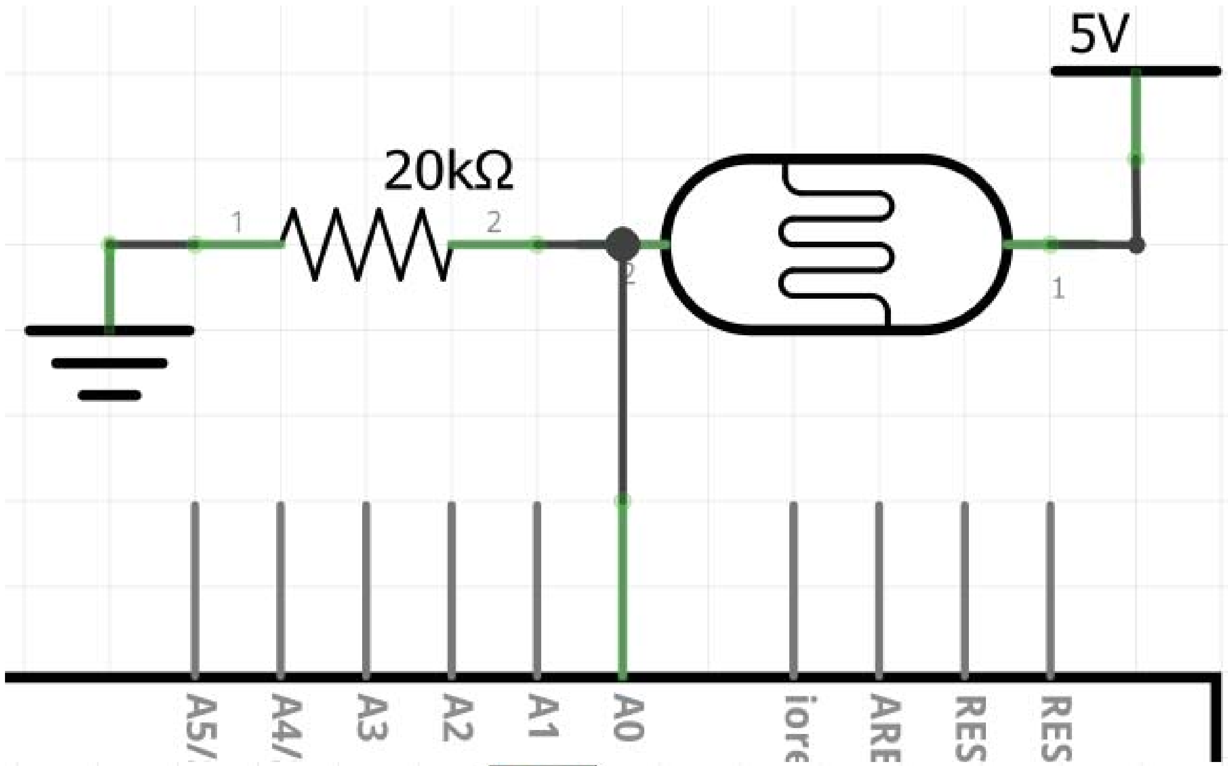
Detection

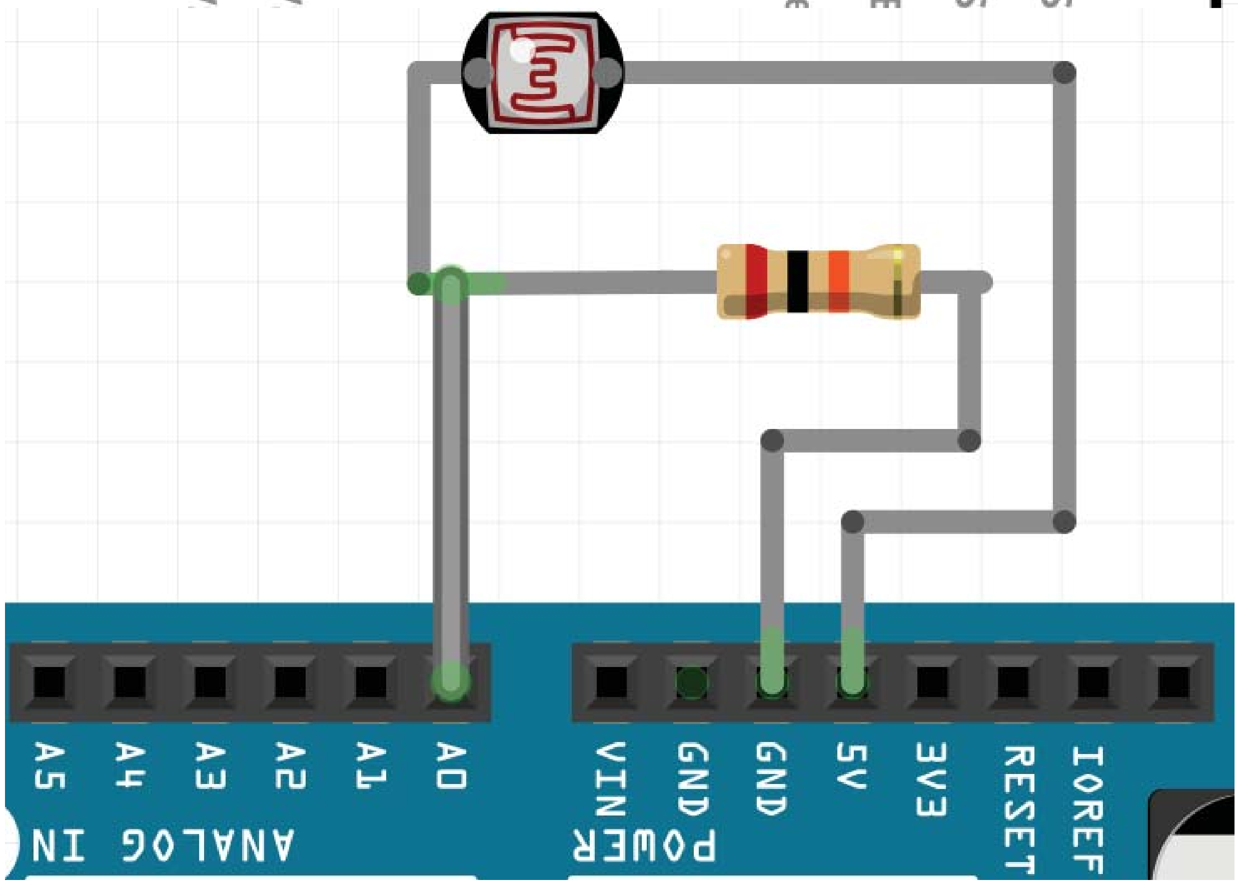
LED





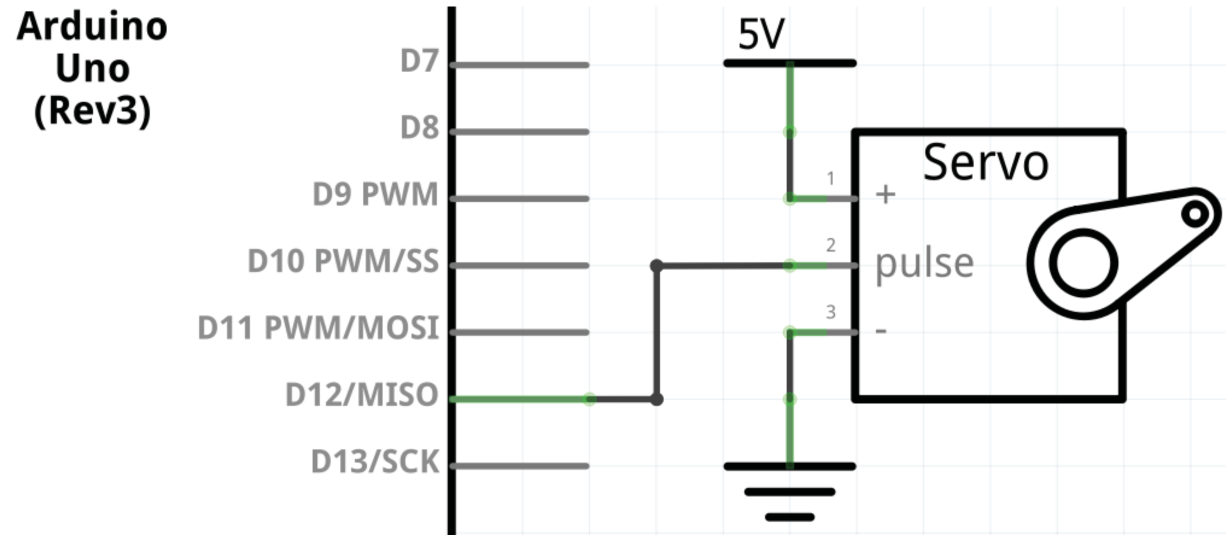
Photoresistor

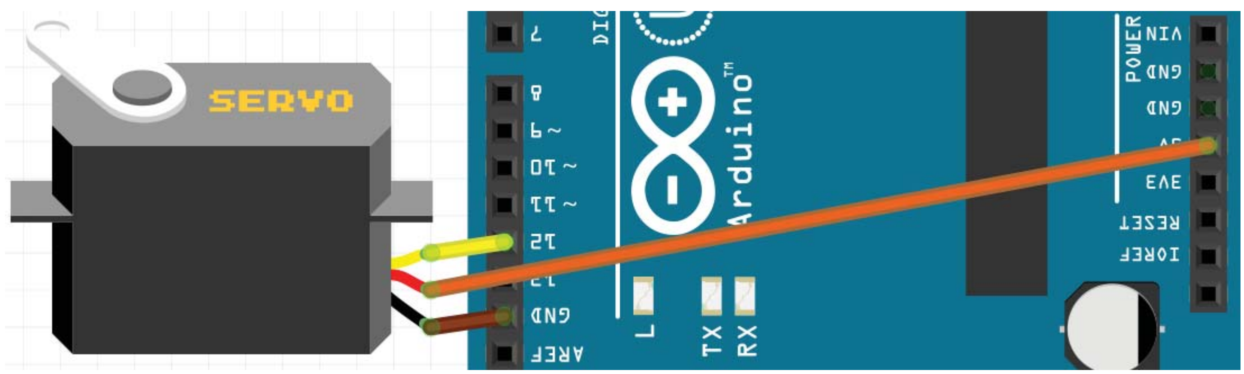




Ball Catch and Release

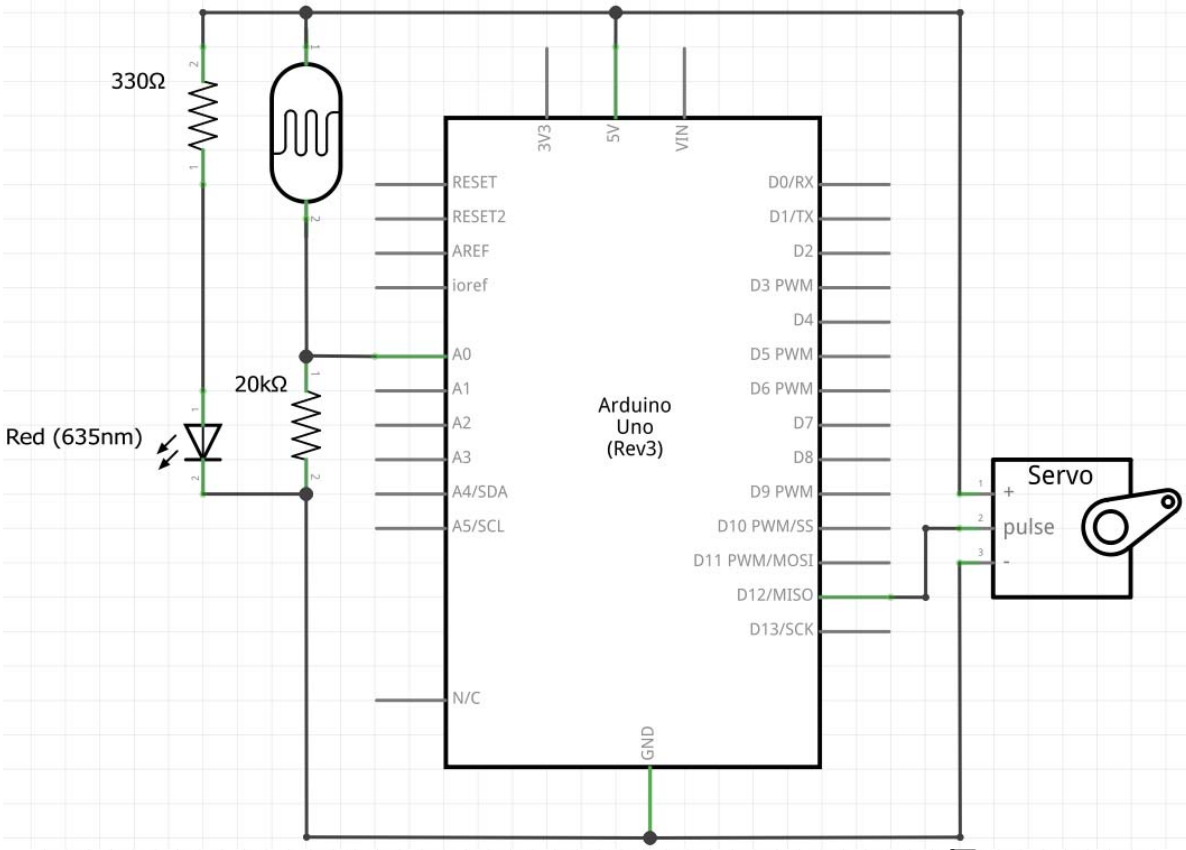
Servo

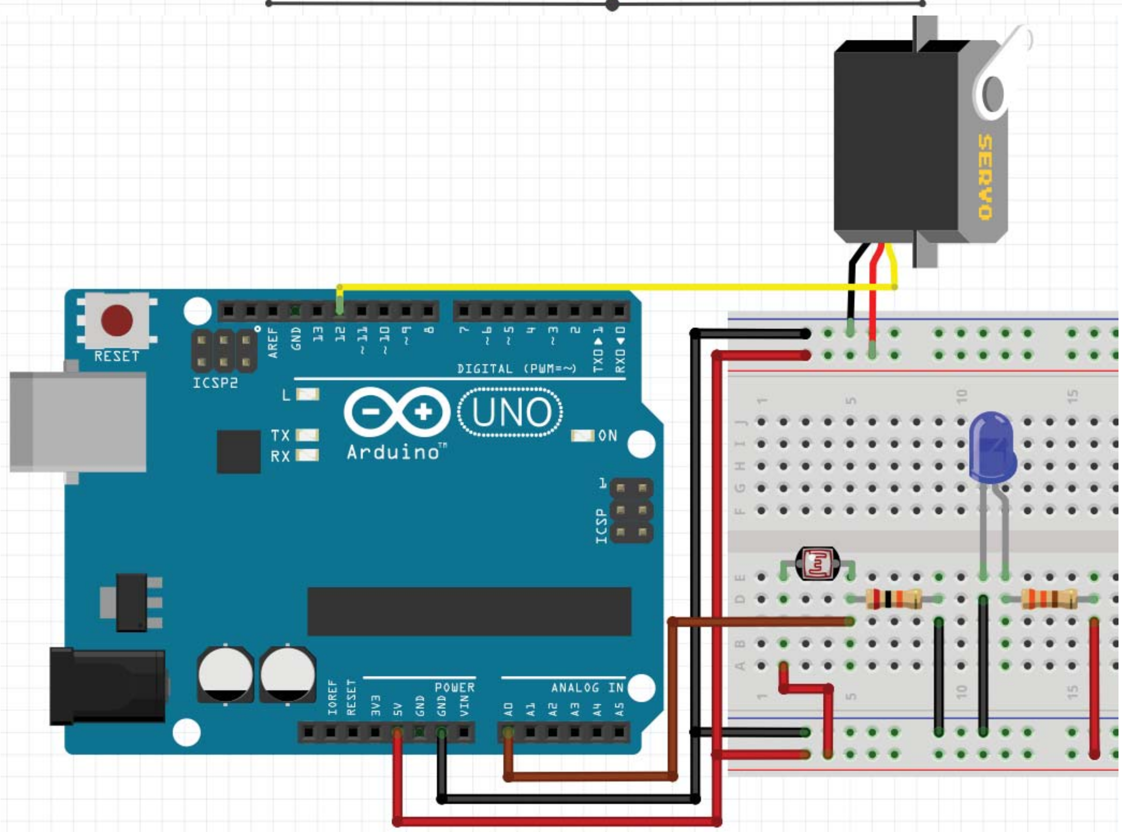




The following electronic diagrams and schematics are for all of the preceding components and how they might be connected using a breadboard:

All Electronics





SECTION 5: PROGRAMMING

```
//TODO: -Adjust delays
//      -Fix serial output

#include <SoftwareSerial.h>
#include <Servo.h>

/*-----------------------------------------------------------------
 ----------------------    VARIABLES   ---------------------------
 ----------------------------------------------------------------*/
// Serial
int baudrate = 57600;

// Servo
Servo myservo;
byte servopin = 12;
int catchangle = 90;          //Servo catch angle (blocking ball)
int releaseangle = 130;       //Servo release angle (allowing ball)

// Debug flag (SERIAL OUTPUT CURRENTLY NOT FUNCTIONING)
boolean debug = false; // true = output messages to serial monitor

// MIDI Shield Variables
SoftwareSerial mySerial(2, 3); // RX, TX
byte i = 0;             //The MIDI note value to be played
byte resetMIDI = 4;     //Tied to VS1053 Reset line (pin)
byte ledPin = 11;       //MIDI traffic inidicator (pin)
int  instrument = 1;    // 1 = Piano

// Music Notes to be played
int note[] = {74, 79, 76}; //Group 31 (key numbers)

// Sensing
int photopin = A0;        //Photoresistor pin
int brightness = 840;     //LED Trigger Brightness (a higher number
// is more sensitive but potentially more prone to false detection)

// LED Pins
byte led = 2; //random?
byte g1 = 5;  //greens
byte g2 = 6;
byte g3 = 7;
byte y1 = 9;  //yellows
byte y2 = 10;
byte r1 = 8;  //reds
byte r2 = 13;

// Delays
//  These are for timing  (all in milliseconds). They should
//  be adjusted based on high-speed footage
int sensetime = 26;    // ball enters box  |--|   ball sensed
int musicstart = 500;  // activating servo |--|   playing music
int note1delay = 500;  // play note 1      |--|   play note 2
```

```
int note2delay = 500;  // play note 2       |--|   play note 3
int releasetime = 500; // play note 3       |--|   release ball
int note3delay = 500;  // release ball      |--|   stop note 3
int balldroptime = 100; // release ball      |--|   ball exits box

/*-----------------------------------------------------------------
 ----------------------  INITIALIZATION  -------------------------
 -----------------------------------------------------------------
 Initialization takes a while so don't drop ball until 1-2s after
 turning the arduino on                                          */
void setup() {

  //Setup serial communication
  Serial.begin(baudrate);
  serialPrint("Initializing...");

  //Setup servo
  myservo.attach(servopin);
  myservo.write(releaseangle); //make sure it's in the open position

  //Setup LEDs
  initializeLEDoutputs();

  //Setup MIDI Shield
  setupMIDI();

  serialPrint("Initialization complete");
  serialPrint("-----------------------");
  serialPrint(" ");
}

/*--------------------------------------------------------------*
 *------------------------  MAIN LOOP  --------------------------*
 *--------------------------------------------------------------*/
void loop() {
  //Read photoresistor value
  int resistorvalue = analogRead(photopin);
  String lightsensor = "Light sensor: ";
  serialPrint(lightsensor + resistorvalue);

  //Check if it is below threshold (ball is passing)
  if (resistorvalue < brightness) {
    String light = "Light : ";
    String lessthanthreshold = " < Threshold: ";
    serialPrint(light + resistorvalue + lessthanthreshold + brightness);
    executeSequence();
  }
  //else
    //Make sure the servo is not blocking the ball path
    //myservo.write(releaseangle);
```

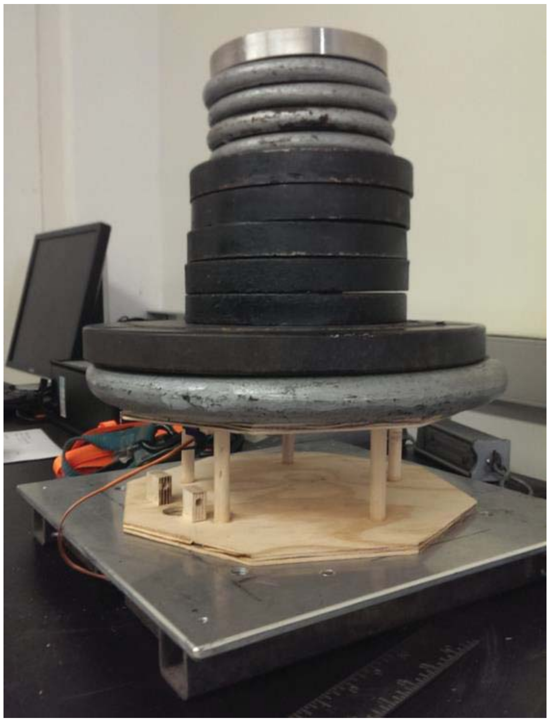
```
serialPrint("----");
serialPrint(" ");

}

/*------------------------------------------------------------
 ------------------------  MAIN HELPER METHODS  ------------------
 ------------------------------------------------------------*/
//This method is called when the ball is detected
//Any kind of light show should be added here, but pay attention
//to the delays, and make sure you're keeping the overall delay
//durations constant
//Currently set up so green LEDs light up as long as ball is in box,
//red LEDs are on as long as servo arm is blocking path, and yellow
//LEDs are on as long as music is playing
void executeSequence() {
  serialPrint("Executing Main Sequence.....");
  setLEDs(HIGH,LOW,LOW,LOW,LOW,LOW,LOW);

  //Activate servo to block ball
  myservo.write(catchangle);
  serialPrint("Servo arm deployed");

  delay(musicstart - sensetime); //compensates for ball in box lost time

  //Some MIDI setup stuff
  talkMIDI(0xB0, 0, 0x79); //Default bank GM1
  talkMIDI(0xC0, instrument, 0); //Set instrument number. 0xC0 is a 1 data byte
command

  //Music should start now

  //Play first note (lasts .5 seconds)
  noteOn(0, note[0], 127); //velocity = 127 (high)
  setLEDs(HIGH,HIGH,LOW,LOW,LOW,HIGH,HIGH);
  serialPrint("Note 1");

  delay(note1delay - 5);

  noteOff(0, note[0], 127);
  delay(5);
  //Play second note (lasts .5 seconds)
  noteOn(0, note[1], 127); //velocity = 127 (fairly high)
  setLEDs(HIGH,LOW,HIGH,LOW,HIGH,LOW,HIGH);
  serialPrint("Note 2");

  delay(note2delay-5);

  noteOff(0, note[1], 127);
  delay(5);
  //Play third note (lasts 1 second)
  noteOn(0, note[2], 127); //velocity = 110 (fairly high)
```

```
  setAllLEDs(HIGH);
  serialPrint("Note 3");

  delay(releasetime-balldroptime);

  //Activate servo to release ball
  myservo.write(releaseangle);
  serialPrint("Servo arm retracted");

  delay(balldroptime);

  serialPrint("Ball out of box");
  setLEDs(LOW,HIGH,HIGH,HIGH,HIGH,HIGH,HIGH); //turns off green LEDs

  delay(note3delay); //hold note for the rest of the time

  noteOff(0, note[2], 127);
  serialPrint("Music stopped playing");
  setAllLEDs(LOW);
}


//A convenient method to bulk change LED values (HIGHs and LOWs)
//Order of parameters are greens, yellows, reds
void setLEDs(boolean g01, boolean g02, boolean g03, boolean y01, boolean y02,
boolean r01, boolean r02){
  digitalWrite(g1, g01);
  digitalWrite(g2, g02);
  digitalWrite(g3, g03);
  digitalWrite(y1, y01);
  digitalWrite(y2, y02);
  digitalWrite(r1, r01);
  digitalWrite(r2, r02);
}

//A convenient method to change ALL LED values to either HIGH or LOW
void setAllLEDs(boolean a) { setLEDs(a,a,a,a,a,a,a); }

//Prints to serial monitor only if debug is true
//CURRENTLY NOT FUNCTIONING
void serialPrint (String message) { if (debug) Serial.println(message); }

/*------------------------------------------------------------------
 --------------------  INITIALIZATION METHODS  -------------------
 ------------------------------------------------------------------*/
void initializeLEDoutputs() {
  pinMode(led, OUTPUT);
  pinMode(g1, OUTPUT);
  pinMode(g2, OUTPUT);
  pinMode(g3, OUTPUT);
  pinMode(r1, OUTPUT);
  pinMode(r2, OUTPUT);
```

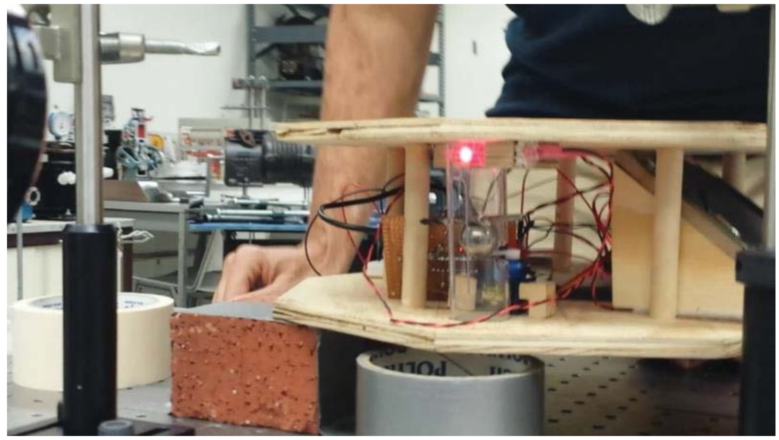
```
  pinMode(y1, OUTPUT);
  pinMode(y2, OUTPUT);
}

void setupMIDI() {
  //Setup soft serial for MIDI control
  mySerial.begin(31250);

  //Reset the VS1053
  pinMode(resetMIDI, OUTPUT);
  digitalWrite(resetMIDI, LOW);
  delay(100);
  digitalWrite(resetMIDI, HIGH);
  delay(100);
  talkMIDI(0xB0, 0x07, 120); //0xB0 is channel message
  //set channel volume to near max (127)
}

/*-----------------------------------------------------------------
 --------------------  MIDI SHIELD METHODS -----------------------
 -----------------------------------------------------------------
 These likely will not or SHOULD NOT be changed                  */

//Send a MIDI note-on message.  Like pressing a piano key
//channel ranges from 0-15
void noteOn(byte channel, byte i, byte attack_velocity) {
  talkMIDI( (0x90 | channel), i, attack_velocity);
}

//Send a MIDI note-off message.  Like releasing a piano key
void noteOff(byte channel, byte i, byte release_velocity) {
  talkMIDI( (0x80 | channel), i, release_velocity);
}

//Plays a MIDI note. Doesn't check to see that cmd is greater than 127, or that
data values are less than 127
void talkMIDI(byte cmd, byte data1, byte data2) {
  digitalWrite(ledPin, HIGH);
  mySerial.write(cmd);
  mySerial.write(data1);

  //Some commands only have one data byte. All cmds less than 0xBn have 2 data
bytes
  //(sort of: http://253.ccarh.org/handout/midiprotocol/)
  if ( (cmd & 0xF0) <= 0xB0)
    mySerial.write(data2);

}
```

PHASE 3: TESTING – REDESIGN – TESTING

SECTION 1: PROTOTYPE TESTING



Here we see a picture of our midterm structure test, when the T.A's put an 80kg load on top of our fabricated music box. As we can see from the picture, our 5-post structure was strong enough to handle all 80 kg's of force downward.



The picture on the left shows the midterm testing of our catch and release mechanisms. As seen in the photo, the ball is in the middle of the drop test. It is about to impact our blocker (the drill bit in the middle), which will decrease the speed of the ball. The red LED is constantly on, providing a constant photosensitivity value for the photoresistor. This picture shows that the ball is pass the photoresistor & LED sensing portion, creating a sudden decrease in photosensivity value. The servo arm, which is activated by this sudden decrease, is now in the process of catching the ball.

This first catch-and-release prototype was successful in catching the ball. It worked for the no box fail and 1 box fail. For two-box fail case, it worked 7 out of 10 times.

Things We Learned:

- Need to slow down the ball near our sensors for better detection
- Tube needed to have cleaner look (no drill tip sticking out!)
- The distance between the sensors and the servo arm needs to be MAXIMIZED!
- The L-servo mount is too small
    - The nail started to crack the wood piece because

SECTION 2: REDESIGN

Pipe Prototype #1: High-Impact Polycarbonate

Our first design iteration for the catch and release pipe was our High-Impact Polycarbonate version. We decided to use polycarbonate in particular because of its transparency. Reason being that we defined one of our customer goods as being able for the user to see the ball through the pipe.

Three key features of this first iteration are the two side holes for the LED and photoresistor sensors, the cut slot for the servo arm, and the blocker in the middle to slow down the ball. This 1'' outer diameter, 1-1/8''High-Impact Polycarbonate tube was ordered from McMaster Carr. The holes and slot were all made using a milling machine for precision. Polycarbonate, being a sensitive plastic, had to be treated with caution. A 1/8'' mill bit was used to avoid fractures or melting of the polycarbonate. The RPM used ranged around 1600, a moderate rate to be using the mill at. The slot was made by taking 0.025'' cuts. The holes were drilled with very cautious and very slow feed rates.

The reason this pipe did not make it to our final prototype is that we found it to be too obtrusive and hard to manufacture the stopping mechanisms for this case. To create the blocker, we had to carefully drill a hole and find a pin with the right size. Even still, the whole design looked bare. We also found that the holes for the LED's and photoresistor did not work well. The holes were too small for reliable interactions.

Pipe Prototype #2: 3-D printed pipe

This pipe was our second iteration of the catch-and-release pipe. This time we went with a 3-D printed pipe made from ABS plastic. We went with 3-D printing because of its ease of manufacturing. This way, we could create any shape or layout we wanted without having to spend hours on the mill.

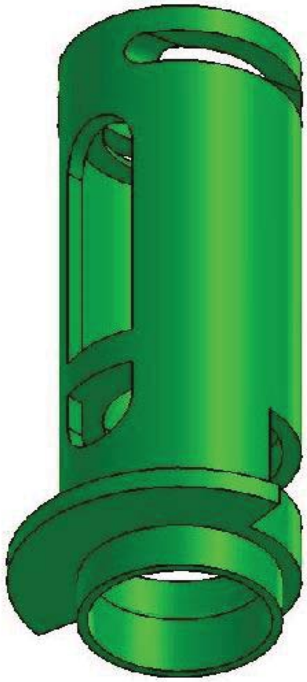
This pipe features two side slots for the passage of light between the LED's and the photoresistor. With the magic of 3-D printing, we did not have to create holes and insert right-fitting pins in them to create our blockers anymore! Instead, we 3-D printed slot extrusions inside the tube. This gave an overall cleaner look to the pipe.

The main downside to 3-D printing is the weakness of the ABS material. As seen in the photo on the side, the main slot we created for the servo arm made the material from the bottom of the slot to the bottom of the tube very slim. This slim material made the strength at that location very low. This led to the shearing of that portion of the tube, as seen from the picture above. Also, the pipe had no mechanism to slow down the ball near the sensors, this led to unreliable sensor readings.

Lessons we learned:

- The height thickness of 3-D printed parts needed to be increased
    - This version's thickness was too small, leading to the fracture
- Stopping mechanisms near the LED/ photoresistor need to be added

Pipe Prototype #3: 3-D printed with orifices



The third and last iteration of the design was a 3-D printed one as well. This time, around, we created orifices near the sensors for reliable readings and at the middle of the tube for slowing down purposes. Like the 3-D pipe before it, we went to Rapidtech to print the tube.

In addition to the new orifices, other new features were a lip that protruded into the bottom hole of the bottom plate and a foot that revolved 180 degrees around the bottom of the pipe. The protruding bottom lip of the tube allows the pipe to make sure it is indeed straight and leveled. The foot allows for more surface area for the attachment of the pipe onto the box. It also helps with the leveling of the pipe to make sure it sits upright between the top and bottom plates of the music box.

We also raised the position of the slot, making it higher so that the height thickness between the slot and the bottom of the tube wasn't too small. As seen in Pipe Prototype #2, a low height thickness resulted in fracture.

This final rendition of the pipe proved successful as the pipe is upright in the box. In addition, we tested the slowing down mechanisms and the orifices do make sure the ball slows down near the sensors for detection as well as slowing down the ball before it hits the servo arm.

Speaker Iteration #1:

Speaker iteration 1 was very barebones in the aspect that its main purpose was to angle the speaker for acoustics.

Features:

- Two plywood side pieces
- One piece of fiberboard to mount the speaker onto the side pieces
- Pieces were attached via wood screws.

Speaker Iteration #2:

Speaker iteration 2 was the final version of this part. Our main intention for this version was to compact the amplifier circuit into the box for simplicity looks. This made us have to make our speaker box assembly wider to incorporate the circuit. We made it wider by making a top piece and cleaner by creating a back piece with two output holes for wires.

Features:

- Extruded cut on one of the speaker side pieces for mounting the potentiometer for volume control
- Expanded area to include amplifier circuit
- Top and back panels to cover internals

SECTION 3: FINAL PRODUCT FABRICATION

For our final iteration of the prototype, we wanted the whole music box to look like a finished product that we could sell in a department store. We painted the box in its entirety and added props such as Lion King themed toys and shrubbery.

In addition, we wanted to pack all our internals as clean as possible. For this reason, we created a 3-D electronics box that houses the batteries, Arduino, MIDI shield, as well as our main circuit board.

Features of the 3-D printed electronics box:

- Two cages for the two 9V batteries
- Output hole for Arduino cable
- Output hole for headphone jack
- Holders for the Arduino board
- Two holes for the LED switches

Our main goal was to package everything without any exposure to our internals. As you can see from the pictures, all our parts are closed

Main features of the final iteration:

- Foam plate with Lion King background photo
- Added 7 LED's for display
  - two red on the foam/background photo
  - two yellow on the foam/background photo
  - 3 green on the bottom plate that is covered by shrubbery
- Painted the entire box according to theme
- Included the lion king figurines & shrubbery props
- Used pipe prototype #3
- Cubic servo mounts (less prone to wood chipping/cracking by the driving screw)
- Used speaker iteration #2

SECTION 4: FINAL PROTOTYPE FIT TESTING

Pictured above are illustrations of our music box in the final fit test during the Senior Winter Design Review. As you can see above, our music box fit and performed just fine!

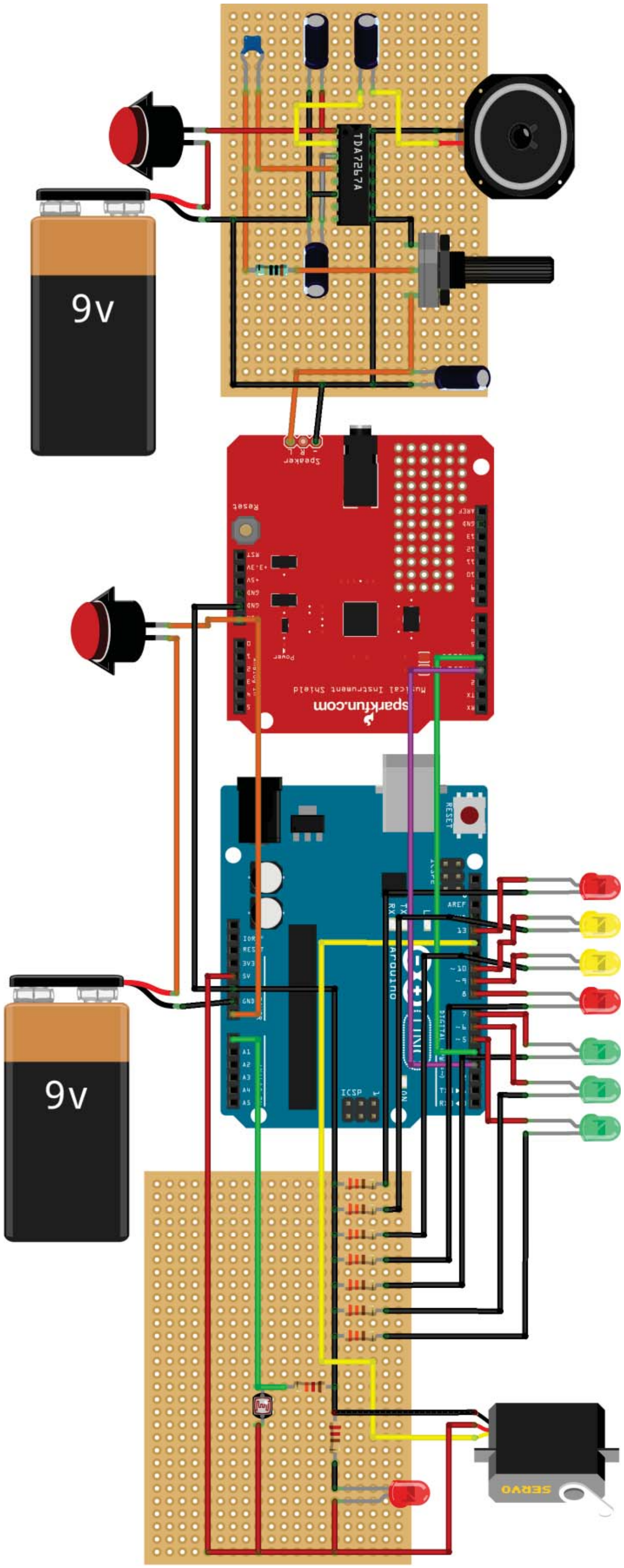
FINAL PRODUCT

SECTION 1: FINAL BIG STACK PICTURES

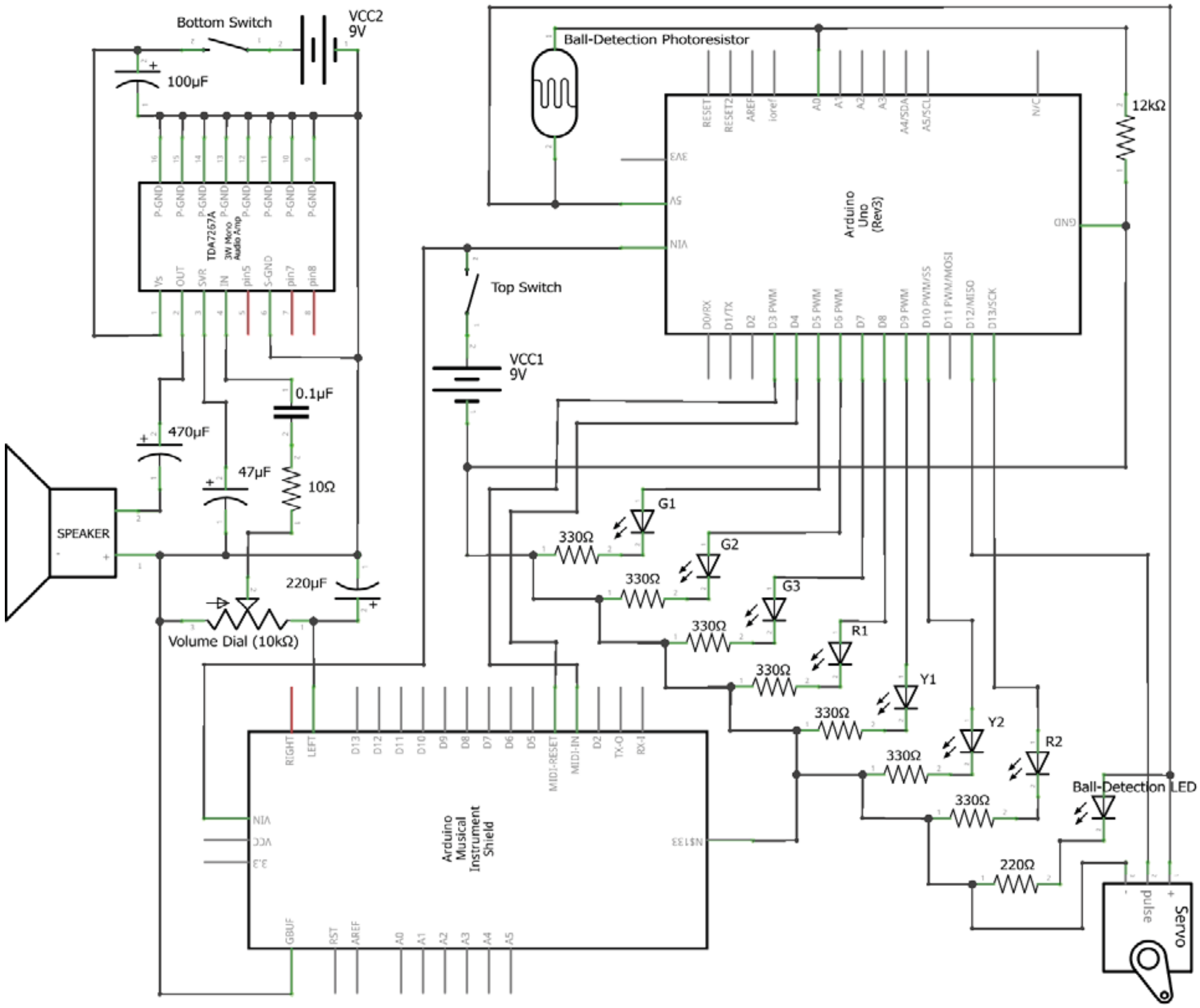
The Final Stack!

The Sub-Stacks!

SECTION 2: FINAL WIRING DIAGRAM

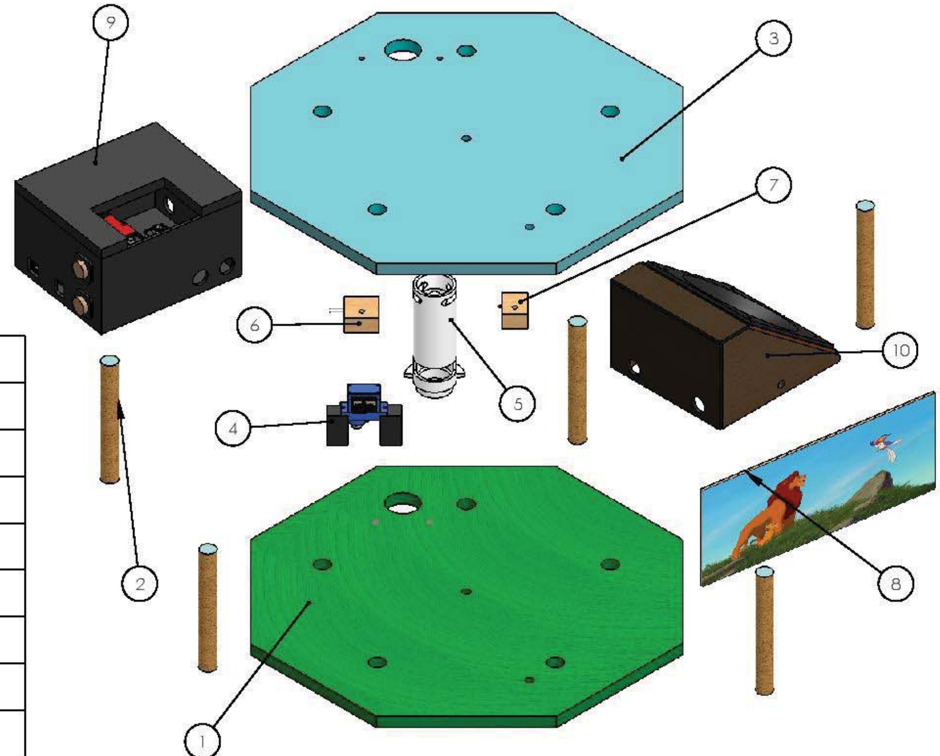

TDA7267A
9v
9v
sparkfun.com
SERVO

Electronic Schematic:



SECTION 3: FINAL DRAWINGS

REV.	DESCRIPTION	EO	APPROVAL	DATE
P1	INITIAL ENGINEERING RELEASE	001	REV. ENG	02/25/14



ITEM NO.	PART NUMBER	QTY.
1	Bottom Plate	1
2	Post	5
3	Topplate	1
4	Servo	1
5	Pipe	1
6	Photoresistor Holder	1
7	LED Holder	1
8	Bacl Panel	1
9	Electronic Enclosure	1
10	Speaker Assembly	1

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES

DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1

63 .002

BREAK SHARP EDGES .01 x 45

PROPRIETARY AND CONFIDENTIAL

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

MAE 151 Music Box

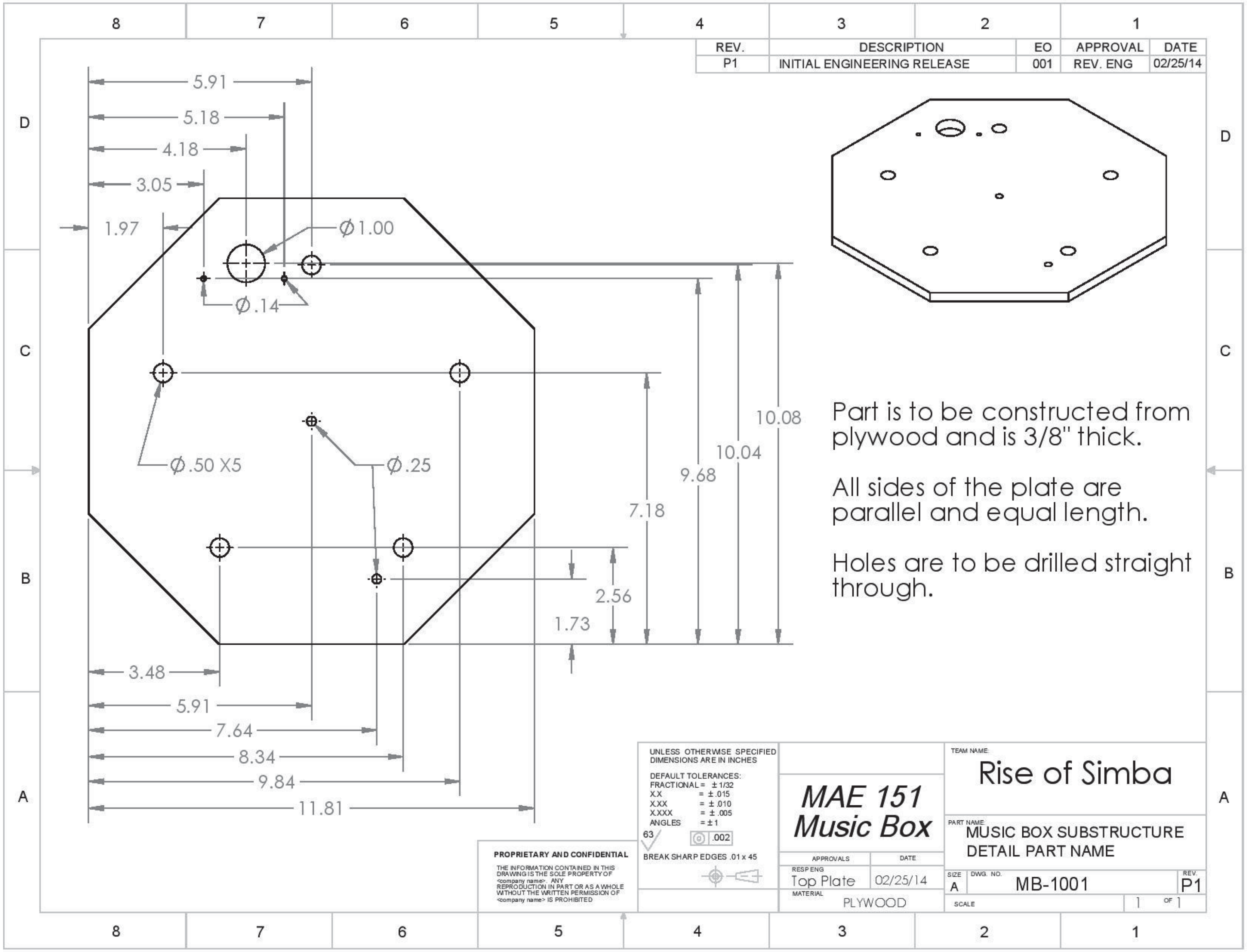
APPROVALS | DATE
RESP ENG: Kushal Shah | 02/25/14
MATERIAL: N/A

TEAM NAME: Lion King Chronicles

PART NAME: Music Box Structure Assembly

SIZE: A | DWG. NO.: MB-100-BOM | REV.: P1

SCALE: 1 | OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
5.91
5.18
4.18
3.05
1.97
Ø1.00
Ø.14
Ø.50 X5
Ø.25
10.08
10.04
9.68
7.18
2.56
1.73
3.48
5.91
7.64
8.34
9.84
11.81
Part is to be constructed from plywood and is 3/8" thick.
All sides of the plate are parallel and equal length.
Holes are to be drilled straight through.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
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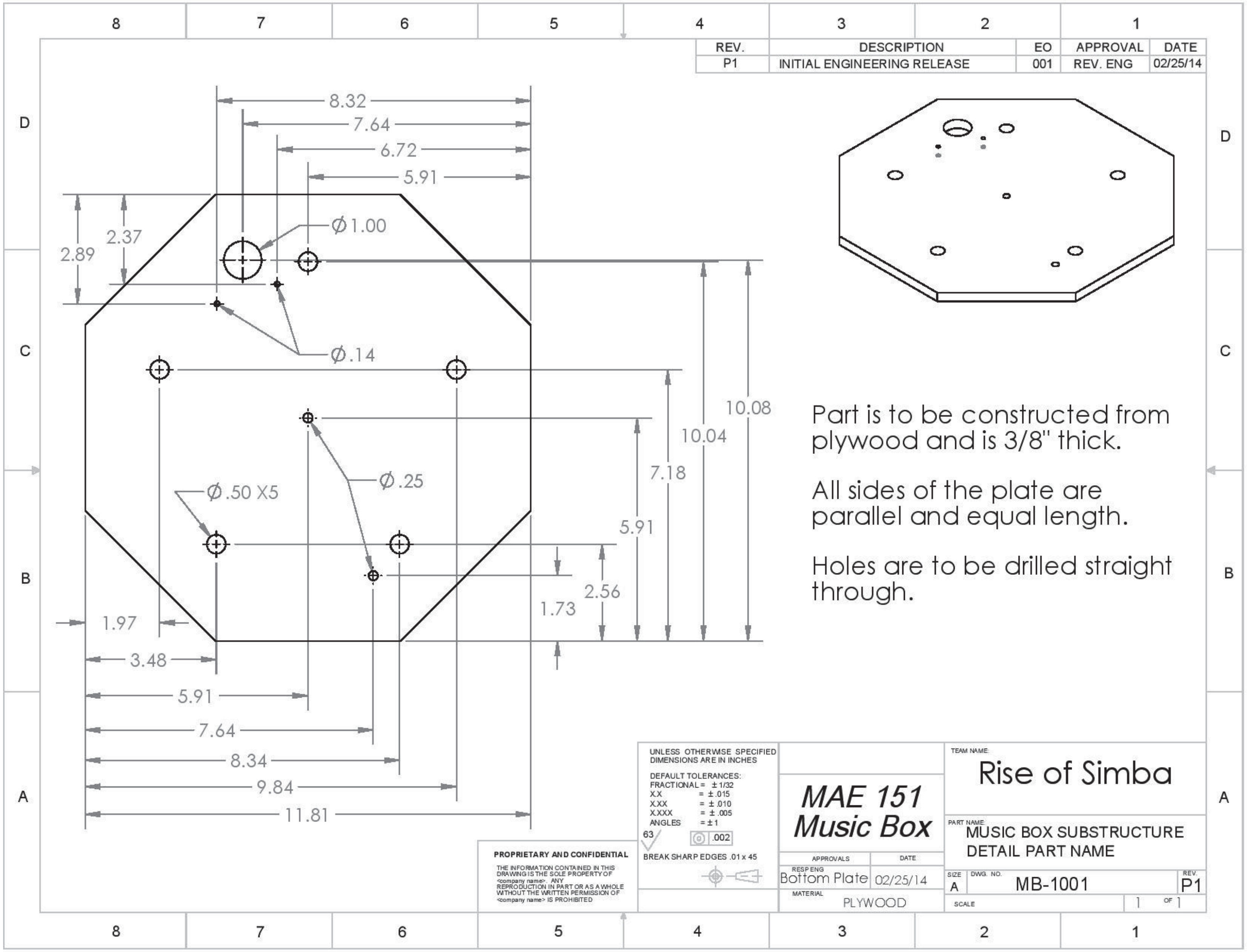
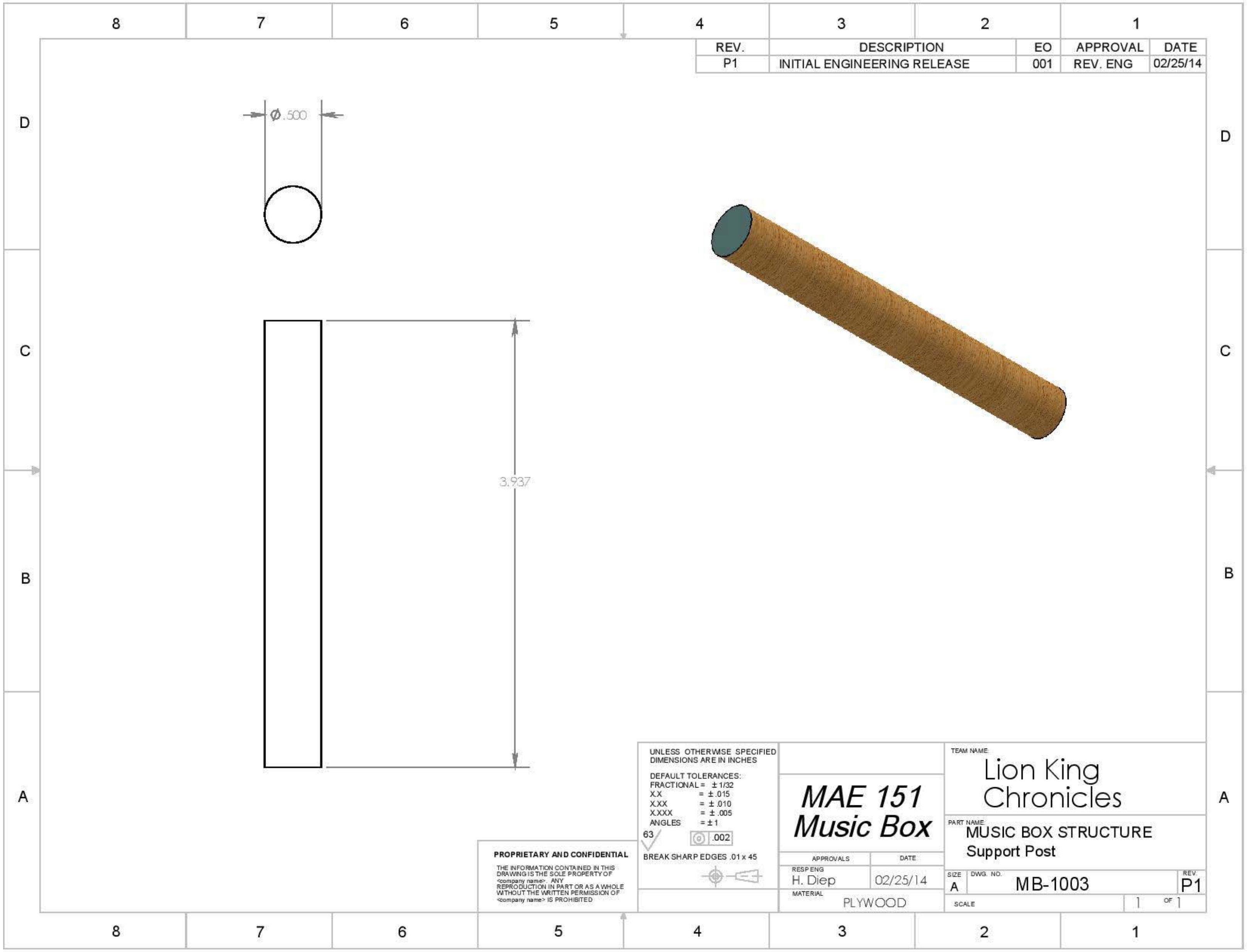
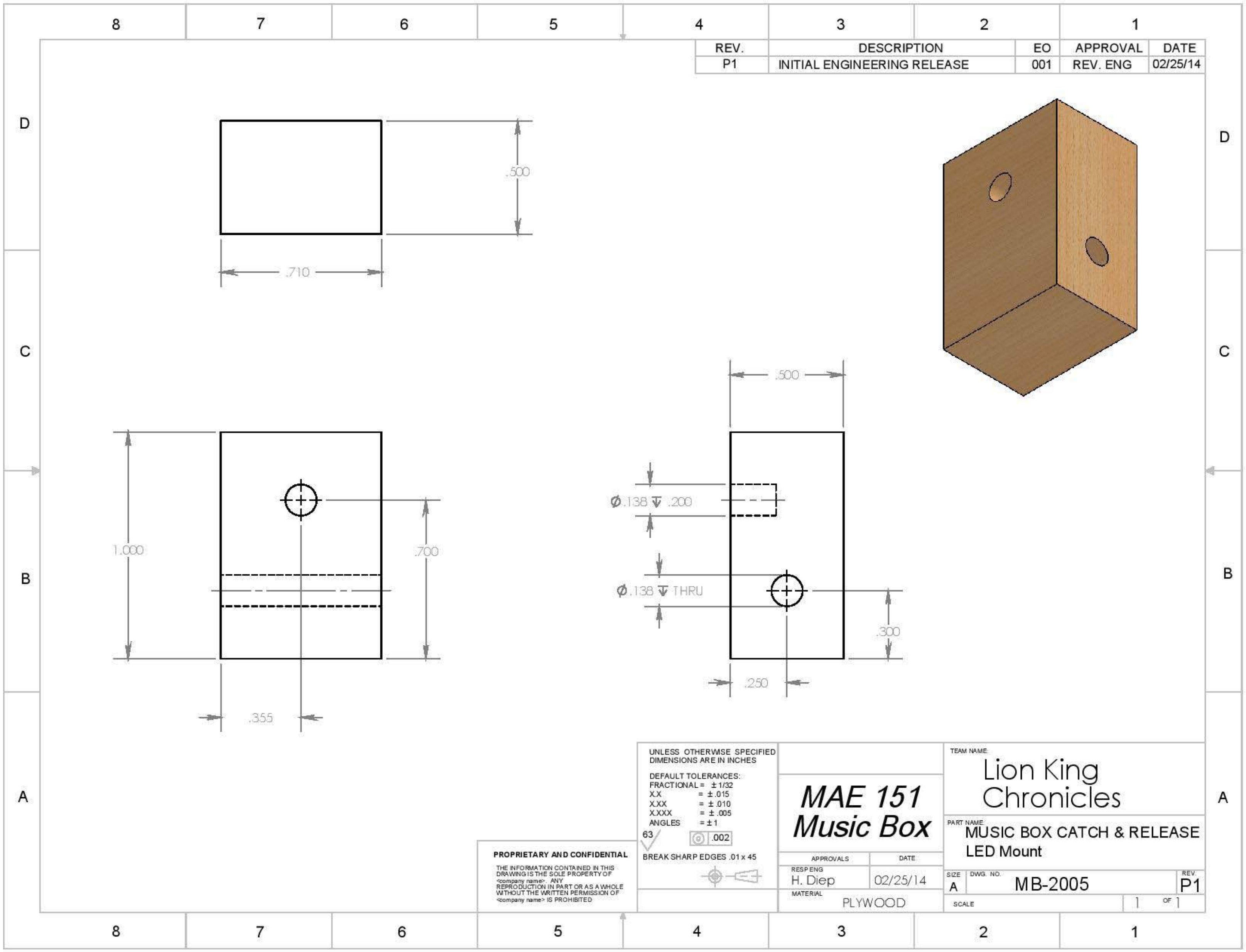
MAE 151 Music Box
APPROVALS
DATE
RESP ENG
Top Plate
02/25/14
MATERIAL
PLYWOOD
TEAM NAME:
Rise of Simba
PART NAME:
MUSIC BOX SUBSTRUCTURE DETAIL PART NAME
SIZE
A
DWG. NO.
MB-1001
REV.
P1
SCALE
1 OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
8.32
7.64
6.72
5.91
2.89
2.37
Ø1.00
Ø.14
Ø.50 X5
Ø.25
10.08
10.04
7.18
5.91
2.56
1.73
1.97
3.48
5.91
7.64
8.34
9.84
11.81
Part is to be constructed from plywood and is 3/8" thick.
All sides of the plate are parallel and equal length.
Holes are to be drilled straight through.
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
MAE 151 Music Box
APPROVALS
DATE
RESP ENG
Bottom Plate
02/25/14
MATERIAL
PLYWOOD
TEAM NAME:
Rise of Simba
PART NAME:
MUSIC BOX SUBSTRUCTURE DETAIL PART NAME
SIZE
A
DWG. NO.
MB-1001
REV.
P1
SCALE
1
OF 1


8 7 6 5 4 3 2 1
D C B A
REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
Ø.500
3.937
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
H. Diep
02/25/14
MATERIAL
PLYWOOD
TEAM NAME
Lion King
Chronicles
PART NAME
MUSIC BOX STRUCTURE
Support Post
SIZE
A
DWG. NO.
MB-1003
REV.
P1
SCALE
1
OF 1



8 7 6 5 4 3 2 1
D C B A
REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
.500
.710
1.000
.700
.355
.500
Ø.138 ↧ .200
Ø.138 ↧ THRU
.300
.250
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ±1/32
XX = ±.015
XXX = ±.010
XXXX = ±.005
ANGLES = ±1
63
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
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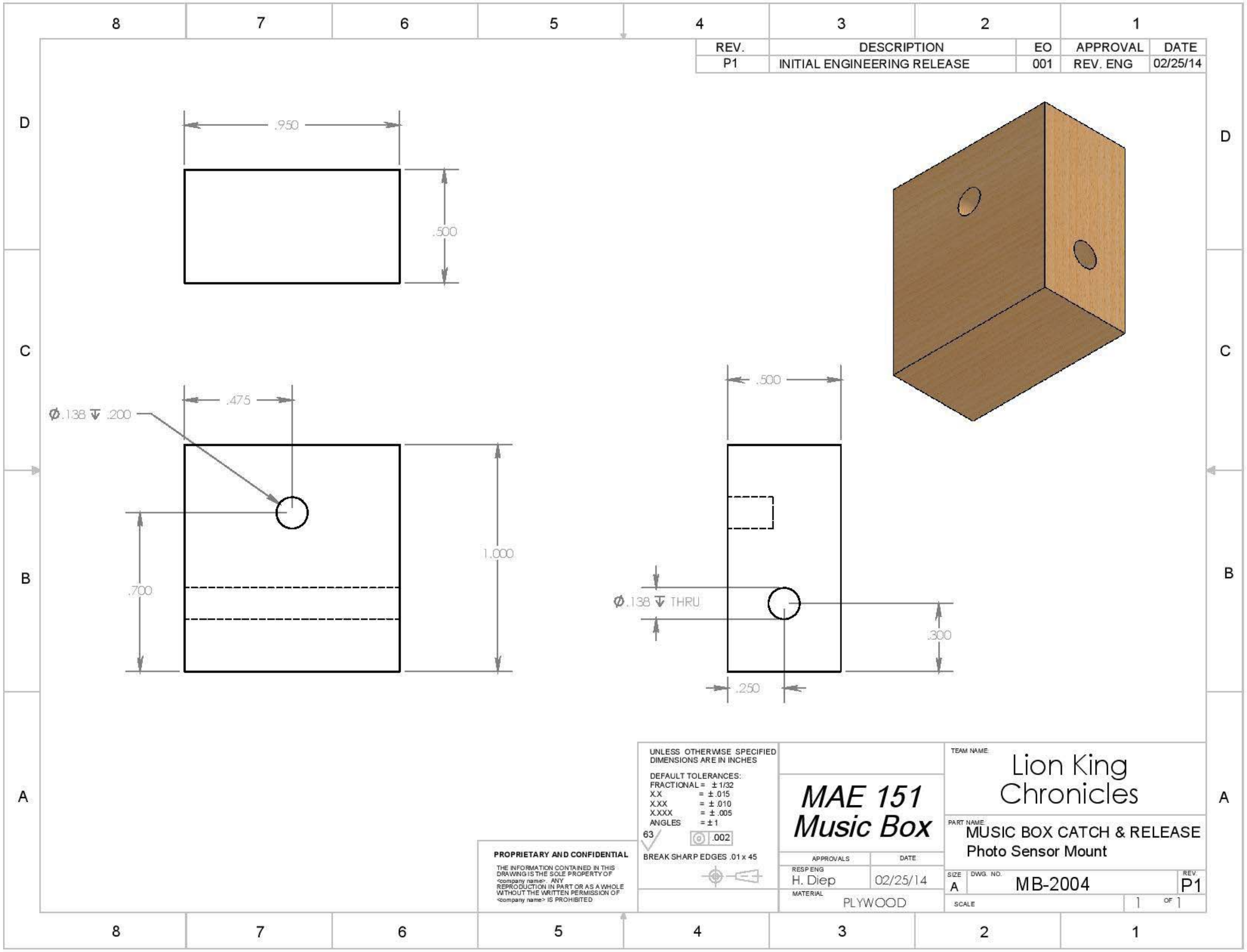
MAE 151 Music Box
APPROVALS
DATE
RESP ENG
H. Diep
02/25/14
MATERIAL
PLYWOOD
TEAM NAME
Lion King Chronicles
PART NAME
MUSIC BOX CATCH & RELEASE LED Mount
SIZE A
DWG. NO. MB-2005
REV P1
SCALE 1 OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
.950
.500
.475
Ø.138 ↧ .200
.700
1.000
.500
Ø.138 ↧ THRU
.300
.250
PROPRIETARY AND CONFIDENTIAL
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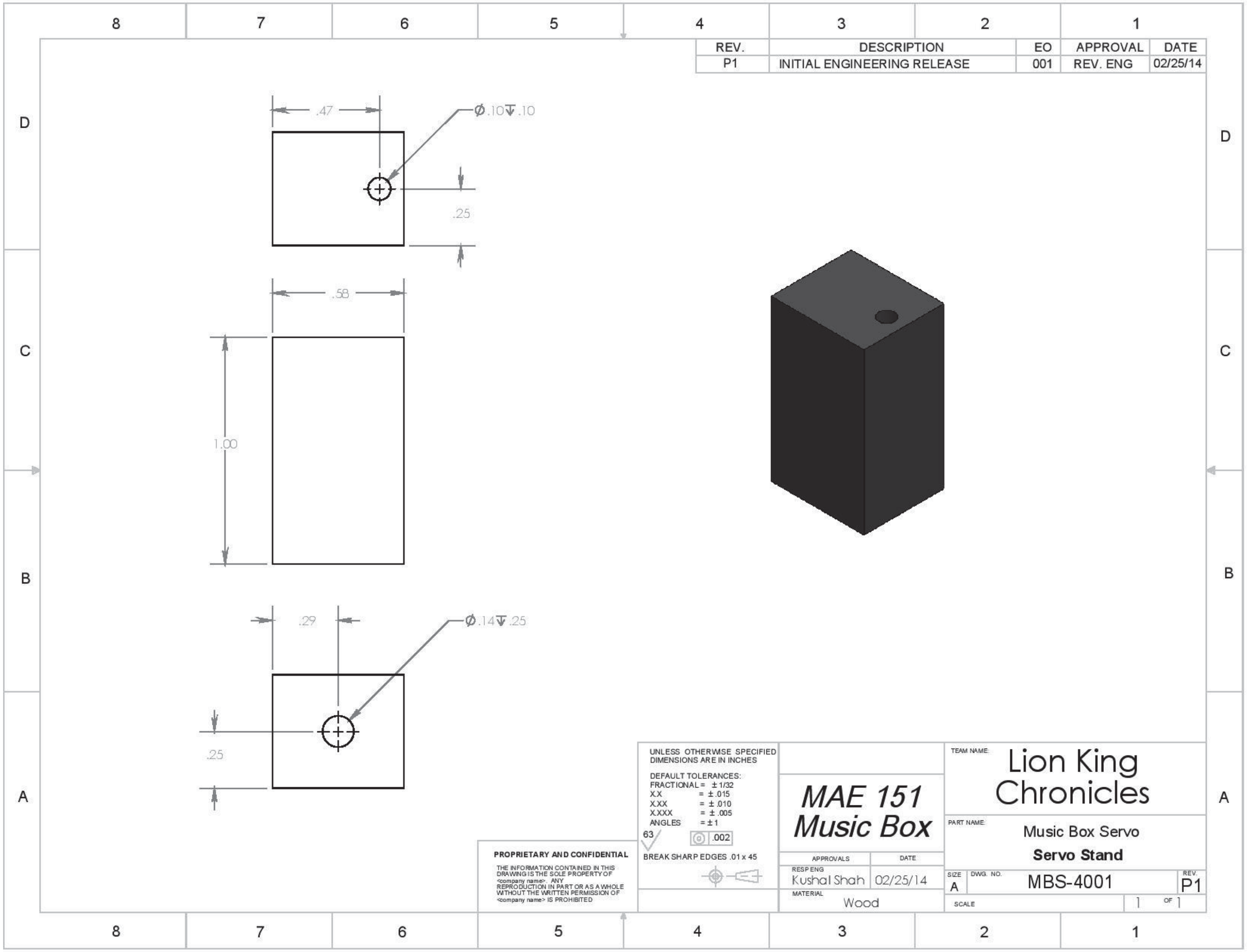
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
H. Diep
02/25/14
MATERIAL
PLYWOOD
TEAM NAME
Lion King Chronicles
PART NAME
MUSIC BOX CATCH & RELEASE
Photo Sensor Mount
SIZE
A
DWG. NO.
MB-2004
REV.
P1
SCALE
1
OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
.47
Ø.10 ↧ .10
.25
.58
1.00
.29
Ø.14 ↧ .25
.25
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
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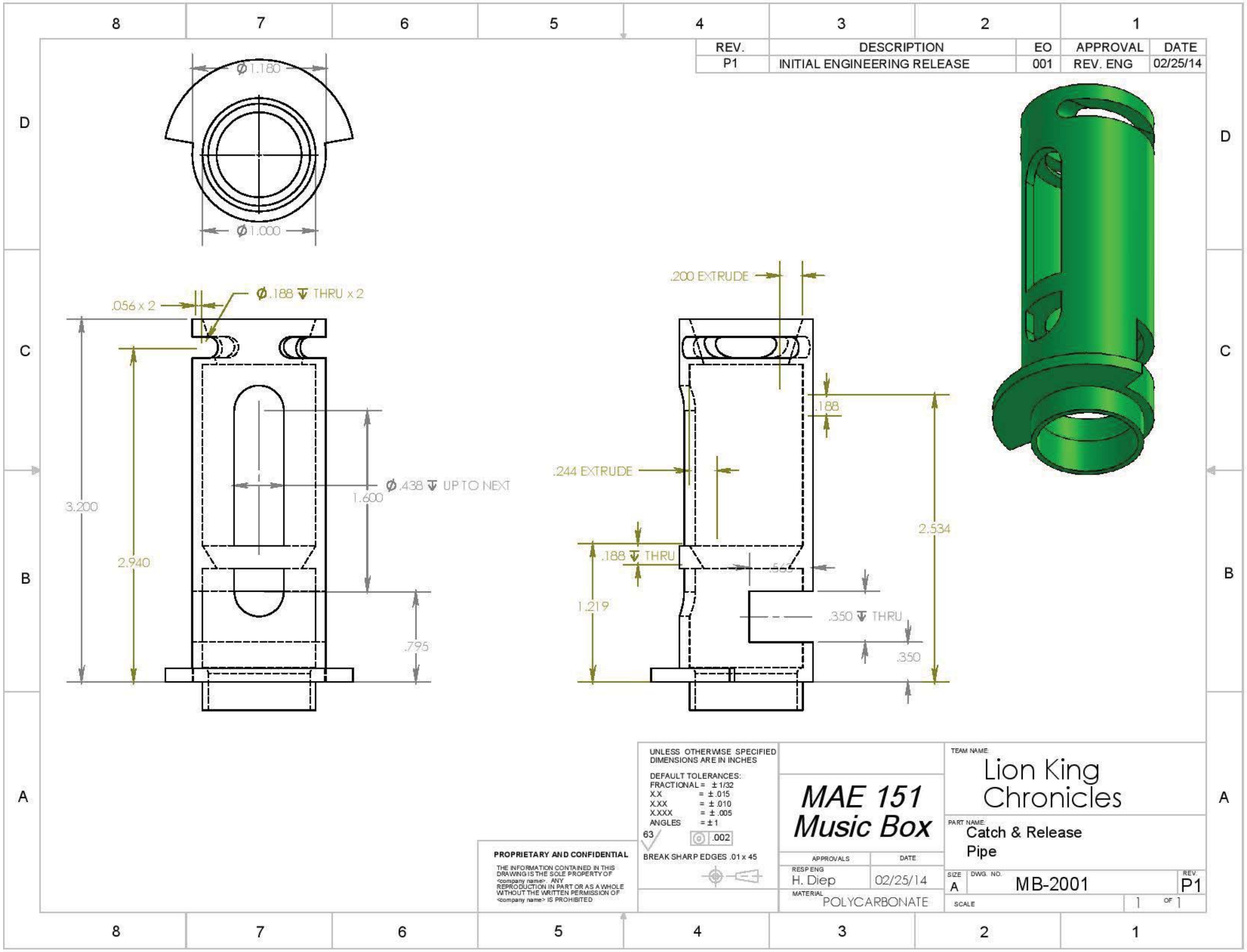
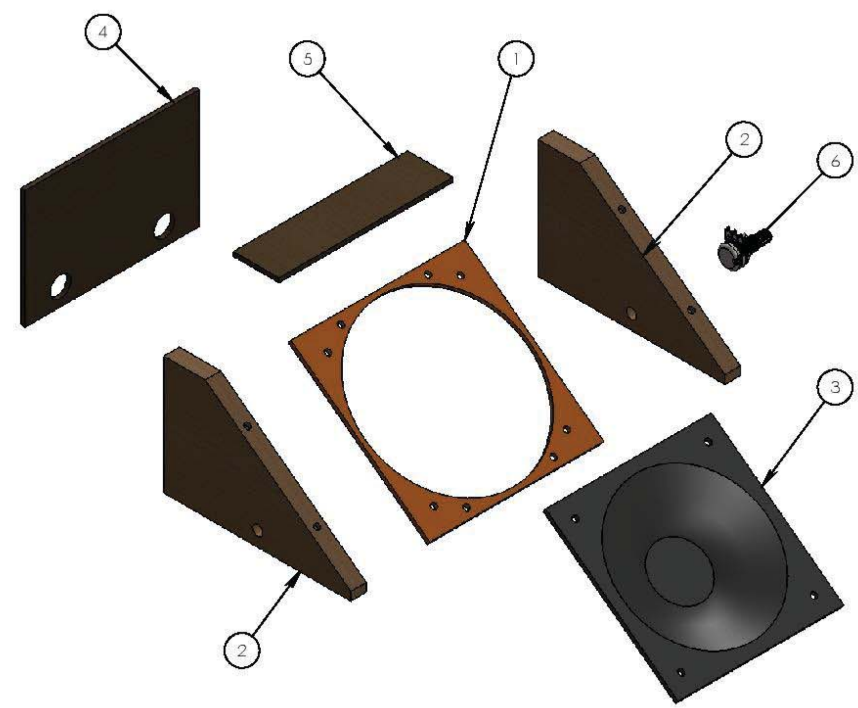
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
Wood
TEAM NAME:
Lion King Chronicles
PART NAME:
Music Box Servo
Servo Stand
SIZE
A
DWG. NO.
MBS-4001
REV.
P1
SCALE
1 OF 1



REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
Ø1.180
Ø1.000
.056 x 2
Ø.188 THRU x 2
3.200
2.940
1.600
Ø.438 UP TO NEXT
.795
.200 EXTRUDE
.244 EXTRUDE
.188
2.534
.188 THRU
1.219
.350 THRU
.350
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <company name>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <company name> IS PROHIBITED
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
H. Diep
02/25/14
MATERIAL
POLYCARBONATE
TEAM NAME:
Lion King Chronicles
PART NAME:
Catch & Release Pipe
SIZE
A
DWG. NO.
MB-2001
REV.
P1
SCALE
1
OF 1

REV.	DESCRIPTION	EO	APPROVAL	DATE
P1	INITIAL ENGINEERING RELEASE	001	REV. ENG	02/25/14



ITEM NO.	PART NUMBER	QTY.
1	MBSP_200_Mount	1
2	MBSP_200_Side	2
3	MBSP_200_Speaker	1
4	MBSP_200_Back	1
5	MBSP_200_Top	1
6	Pot	1

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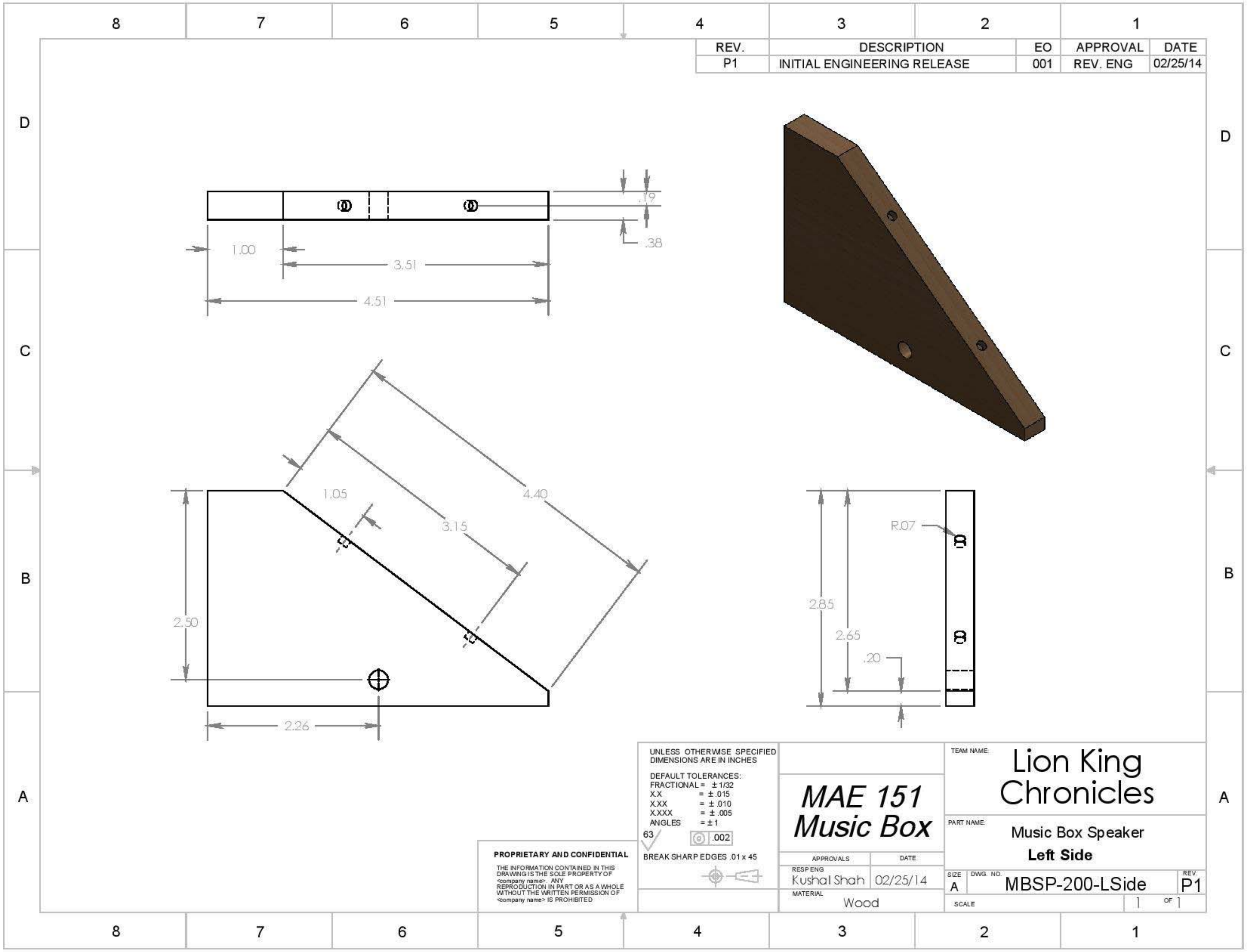
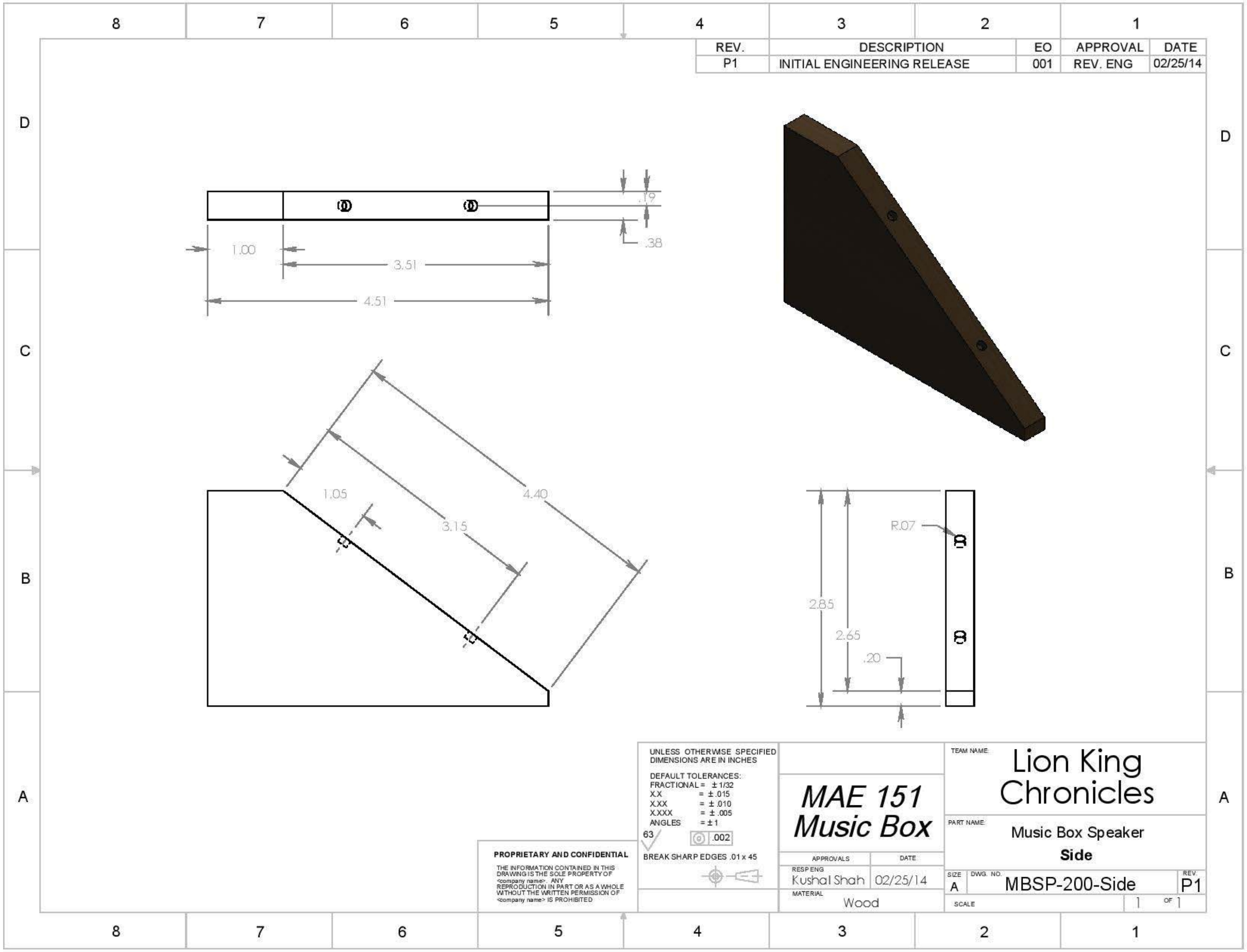
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45

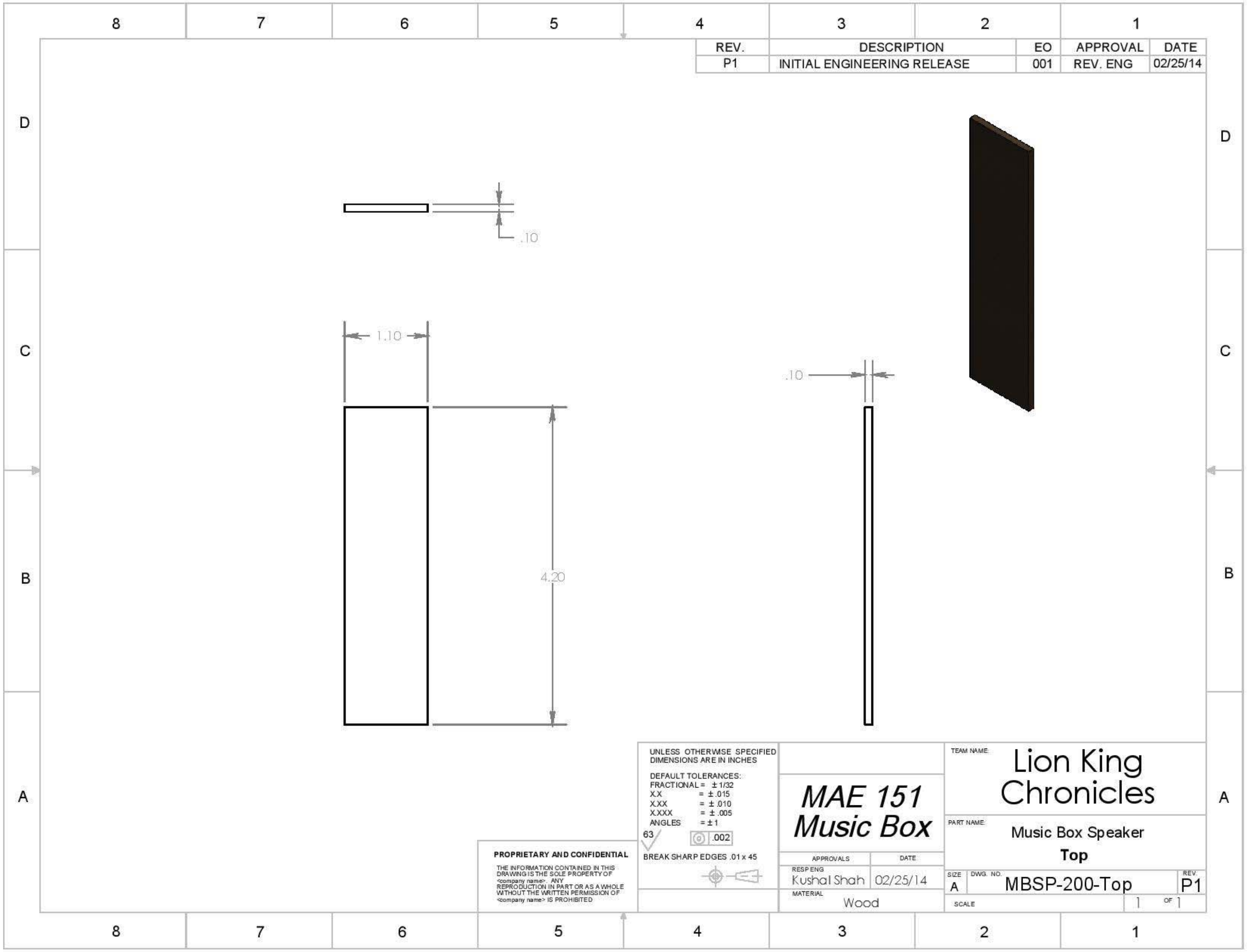
MAE 151 Music Box

APPROVALS | DATE
RESP ENG: Kushal Shah | 02/25/14
MATERIAL: N/A

TEAM NAME: Lion King Chronicles
PART NAME: Music Box Speaker Assembly BOM
SIZE: A | DWG. NO. MBSP-200-BOM | REV. P1
SCALE: 1 | OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
.19
.38
1.00
3.51
4.51
1.05
3.15
4.40
2.50
2.26
R.07
2.85
2.65
.20
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <company name>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <company name> IS PROHIBITED
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
MAE 151 Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
Wood
TEAM NAME
Lion King Chronicles
PART NAME
Music Box Speaker
Left Side
SIZE
A
DWG. NO.
MBSP-200-LSide
REV
P1
SCALE
1
OF 1


REV.
P1
DESCRIPTION
INITIAL ENGINEERING RELEASE
EO
001
APPROVAL
REV. ENG
DATE
02/25/14
.19
.38
1.00
3.51
4.51
1.05
3.15
4.40
R.07
2.85
2.65
.20
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
Wood
TEAM NAME
Lion King Chronicles
PART NAME
Music Box Speaker
Side
SIZE
A
DWG. NO.
MBSP-200-Side
REV.
P1
SCALE
1
OF 1


REV.
P1
DESCRIPTION
INITIAL ENGINEERING RELEASE
EO
001
APPROVAL
REV. ENG
DATE
02/25/14
.10
1.10
4.20
.10
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
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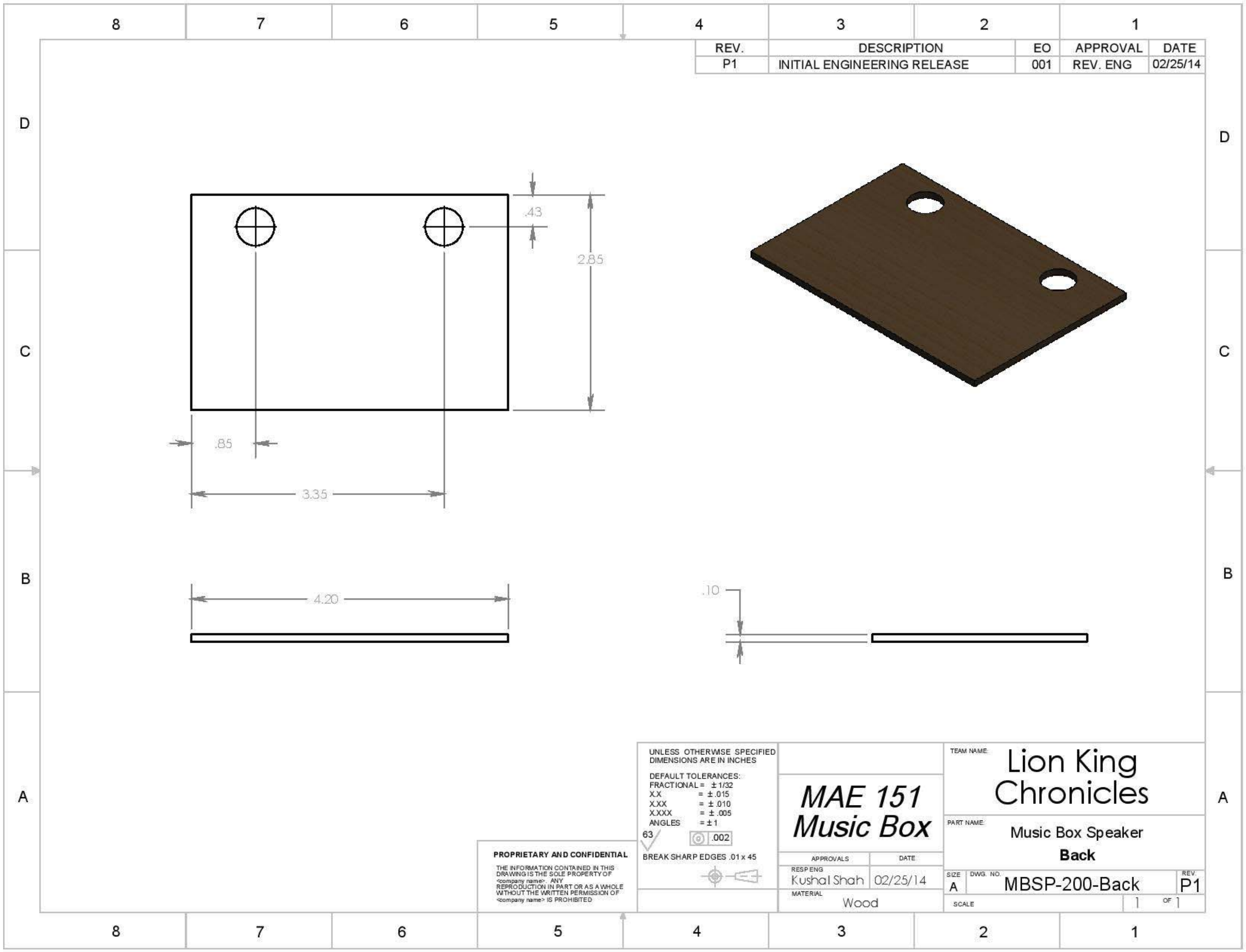
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
Wood
TEAM NAME
Lion King
Chronicles
PART NAME
Music Box Speaker
Top
SIZE
A
DWG. NO.
MBSP-200-Top
REV.
P1
SCALE
1 OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
.43
2.85
.85
3.35
4.20
.10
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
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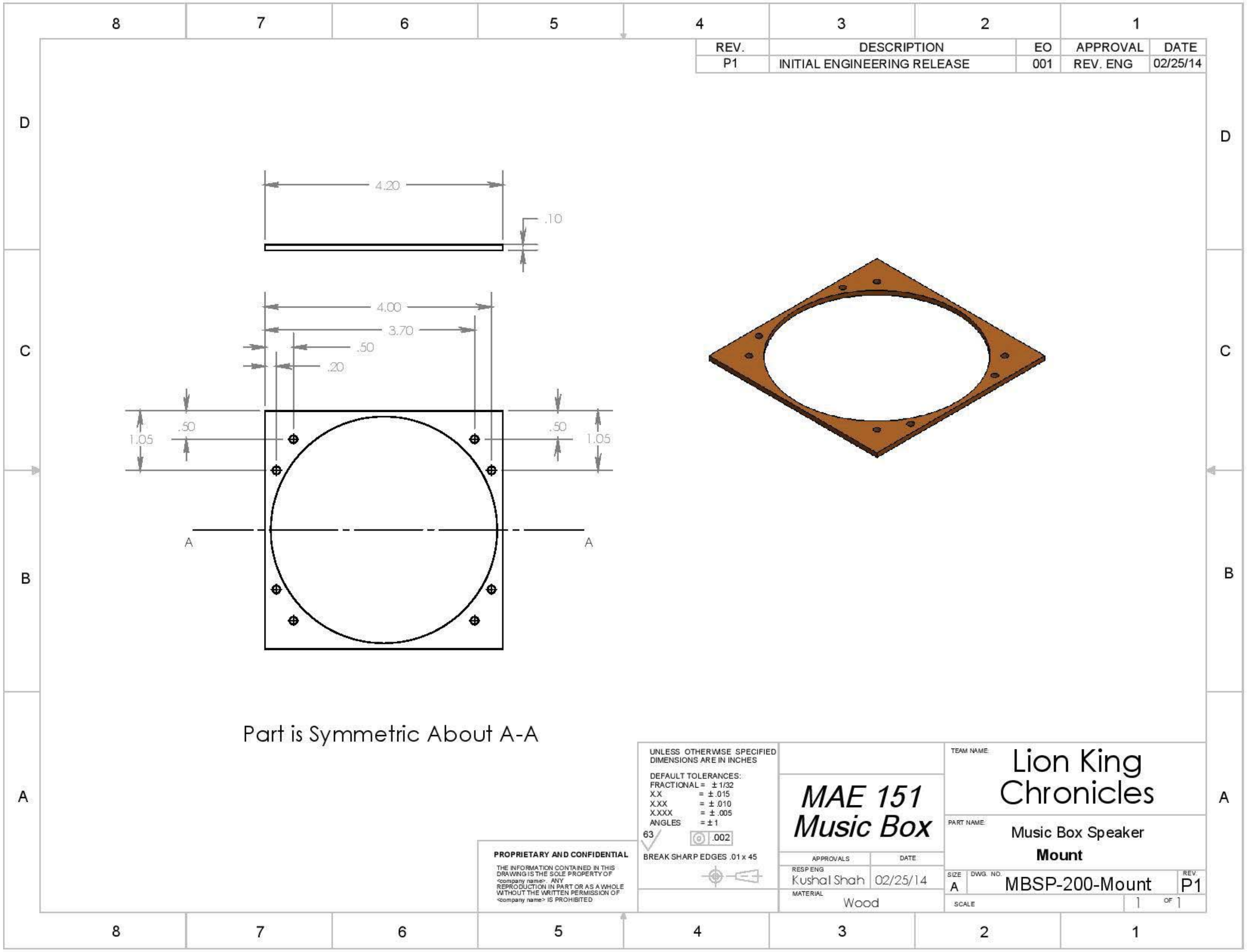
MAE 151 Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
Wood
TEAM NAME
Lion King Chronicles
PART NAME
Music Box Speaker Back
SIZE
A
DWG. NO.
MBSP-200-Back
REV.
P1
SCALE
1
OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
4.20
.10
4.00
3.70
.50
.20
.50
1.05
A
A
Part is Symmetric About A-A
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <company name>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <company name> IS PROHIBITED
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
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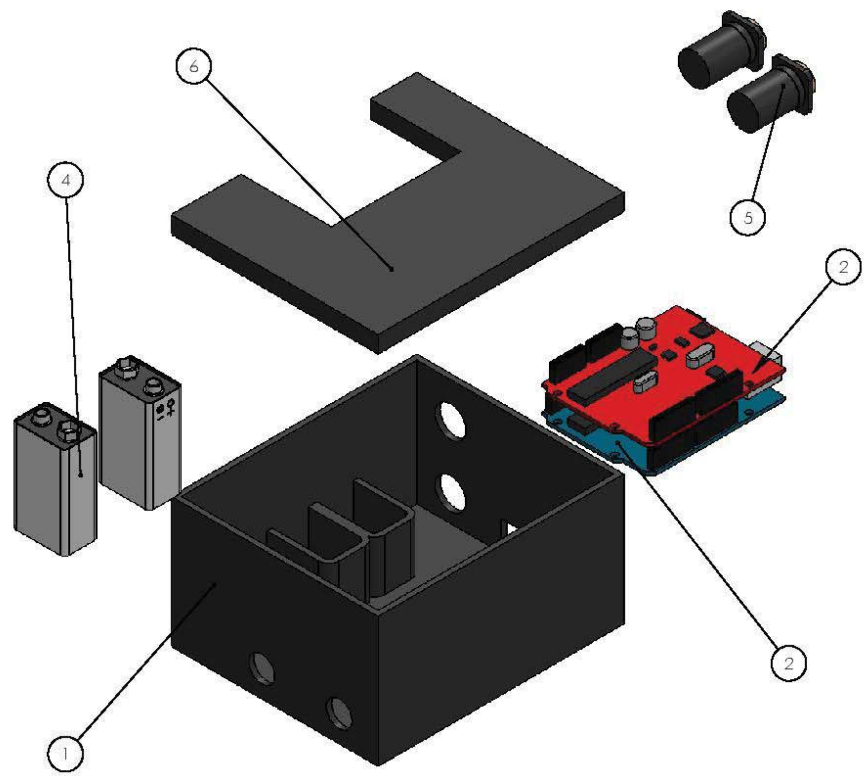
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
MAE 151 Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
Wood
TEAM NAME:
Lion King Chronicles
PART NAME:
Music Box Speaker Mount
SIZE
A
DWG. NO.
MBSP-200-Mount
REV.
P1
SCALE
1
OF 1

REV.	DESCRIPTION	EO	APPROVAL	DATE
P1	INITIAL ENGINEERING RELEASE	001	REV. ENG	02/25/14

ITEM NO.	PART NUMBER	QTY.
1	Enclosure	1
2	Arduino Uno	1
3	Music Shield	1
4	9 V - Battery	2
5	Push Switch	2
6	Enclosure Lid	1



PROPRIETARY AND CONFIDENTIAL
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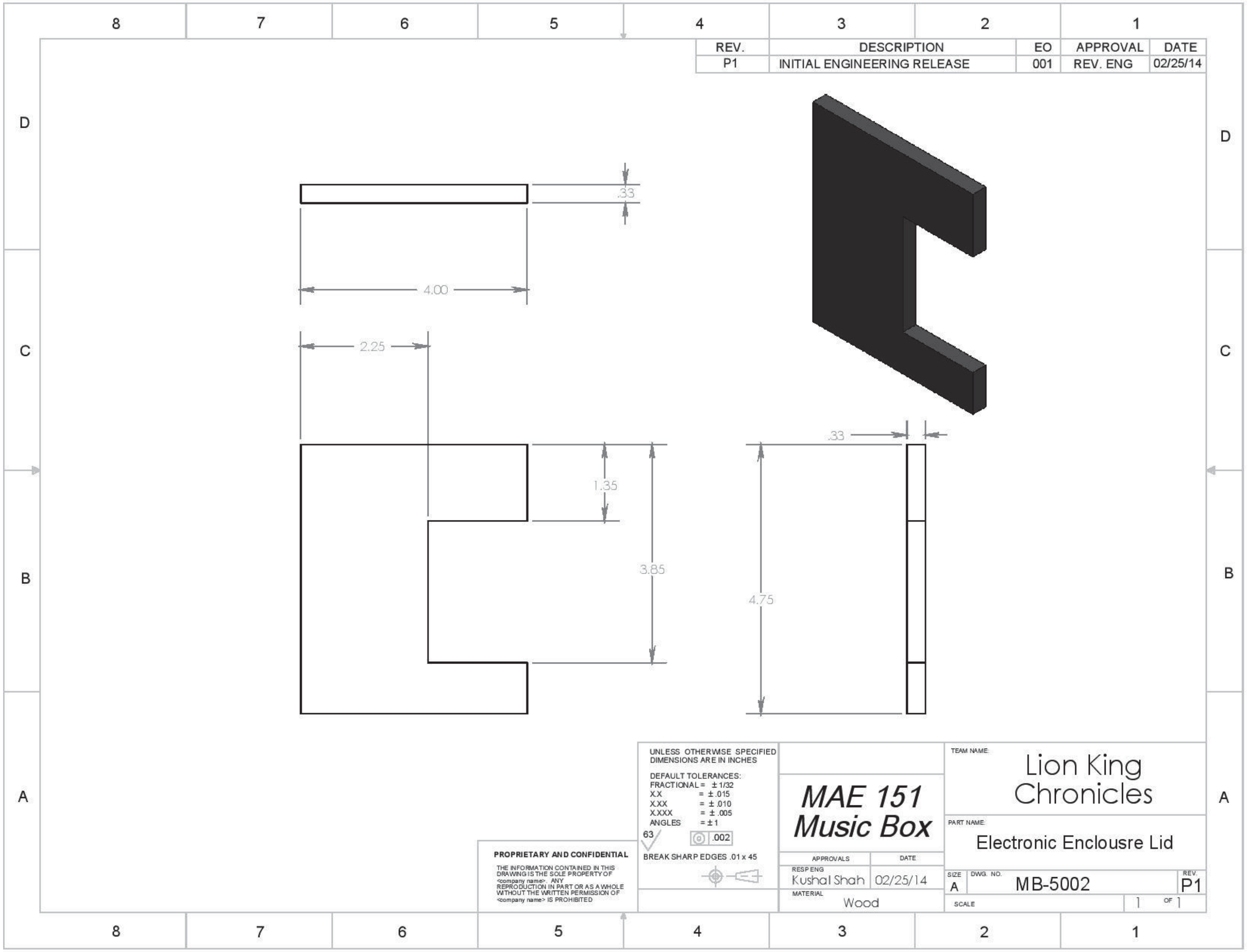
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45

MAE 151 Music Box

APPROVALS	DATE
RESP ENG Kushal Shah	02/25/14
MATERIAL Wood	

TEAM NAME: Lion King Chronicles
PART NAME: Electronic Enclousre Lid
SIZE A | DWG. NO. MB-5000 | REV. P1
SCALE | 1 OF 1


REV.
P1
DESCRIPTION
INITIAL ENGINEERING RELEASE
EO
001
APPROVAL
REV. ENG
DATE
02/25/14
.33
4.00
2.25
1.35
3.85
4.75
.33
PROPRIETARY AND CONFIDENTIAL
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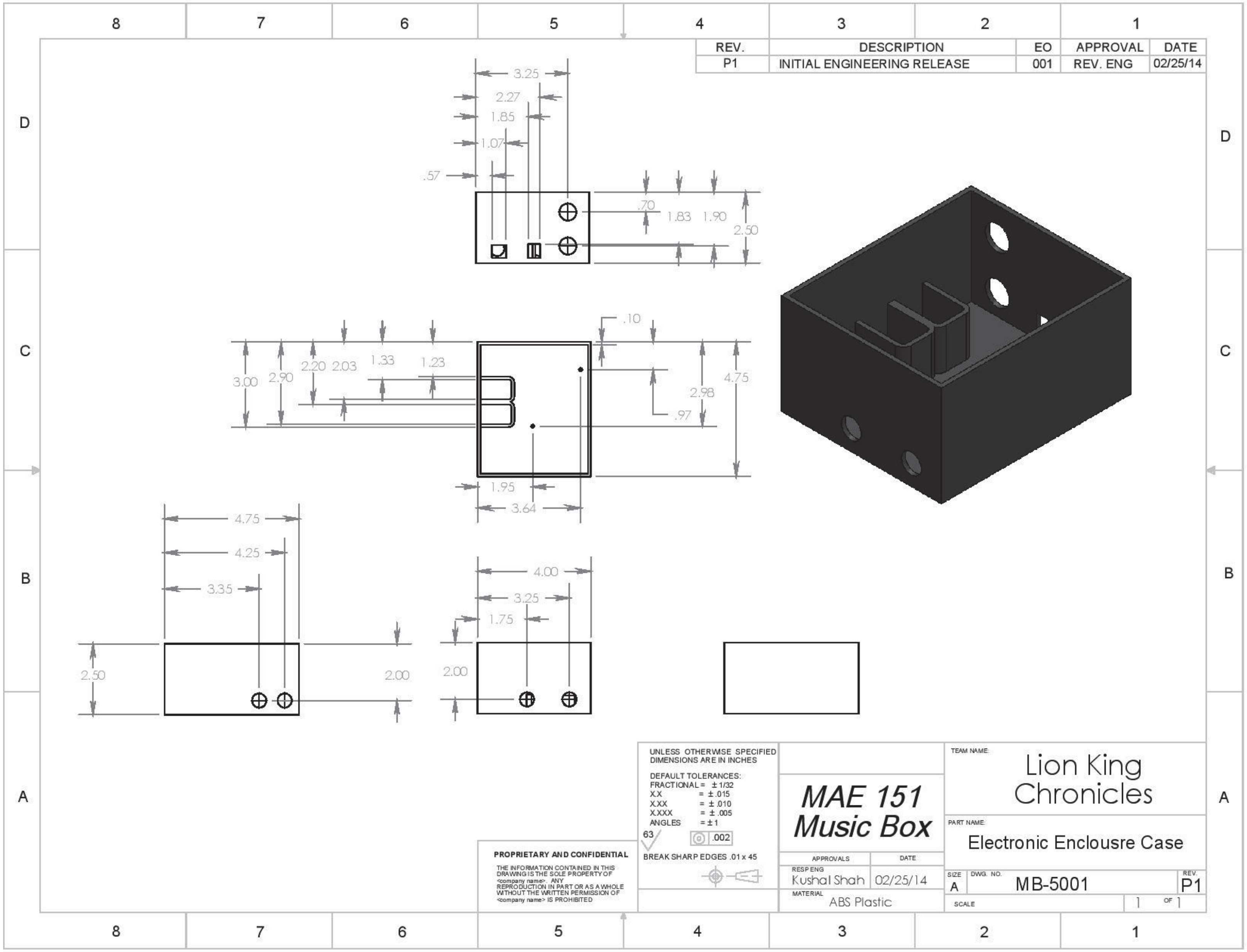
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
Wood
TEAM NAME:
Lion King Chronicles
PART NAME:
Electronic Enclousre Lid
SIZE
A
DWG. NO.
MB-5002
REV.
P1
SCALE
1
OF 1


REV. | DESCRIPTION | EO | APPROVAL | DATE
P1 | INITIAL ENGINEERING RELEASE | 001 | REV. ENG | 02/25/14
3.25
2.27
1.85
1.07
.57
.70
1.83
1.90
2.50
.10
3.00
2.90
2.20
2.03
1.33
1.23
2.98
.97
4.75
1.95
3.64
4.75
4.25
3.35
2.50
2.00
4.00
3.25
1.75
2.00
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEFAULT TOLERANCES:
FRACTIONAL = ± 1/32
X.X = ± .015
X.XX = ± .010
X.XXX = ± .005
ANGLES = ± 1
63
.002
BREAK SHARP EDGES .01 x 45
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <company name>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <company name> IS PROHIBITED
MAE 151
Music Box
APPROVALS
DATE
RESP ENG
Kushal Shah
02/25/14
MATERIAL
ABS Plastic
TEAM NAME:
Lion King Chronicles
PART NAME:
Electronic Enclousre Case
SIZE
A
DWG. NO.
MB-5001
REV.
P1
SCALE
1
OF 1

SECTION 5: FINAL BOM

MAE 151 Music Box BOM

Item	Description	Qty	Unit Price	Total price
Wood				
Ply Wood	12"x12"x3/8"	2	$ 1.00	$ 2.00
Ply Wood	2"x12"x3/8"	1	$ 0.16	$ 0.16
Ply Wood	4"x4"x3/8"	1	$ 0.11	$ 0.11
Fiberboard	24"x24"x1/8"	1	$ 2.60	$ 2.60
Wood Post	1/2" diameter hardwood dowel ($0.033/in)	20 inches	$0.033/in	$ 0.66
Dowl Pin	¼ Diameter Fluted Dowel Pins Model 840014 (72 - $2.89)	1	$ 0.04	$ 0.04
Adhesives/Fasteners				
Screws	#6-1/2 zinc plated flat head wood screws (100-$3.82)	10	$ 0.04	$ 0.38
Screws	#6-1 1/4 zinc plated flat head wood screws (100 - $4.98)	4	$ 0.05	$ 0.20
Wood Glue	Gorilla Glue brand, 2 fl. oz.	1	$ 5.97	$ 5.97
Epoxy	Loctite brand, 7 fl. oz.	1	$ 5.47	$ 5.47
Velcro	3-1/2" x 3/4" strips	1	$ 2.98	$ 2.98
Threaded Stud	1/4"-20 wood screw threaded stud	1	$ 0.21	$ 0.21
Electronics System				
Speaker	5W / 8 ohm Workman brand SA-400 -	1	$ 2.70	$ 2.70
Capacitor	0.1uF	1	$ 0.13	$ 0.13
Capacitor	47uF	1	$ 1.49	$ 1.49
Capacitor	100uF	1	$ 0.13	$ 0.13
Capacitor	220uF	1	$ 1.49	$ 1.49
Capacitor	470uF	1	$ 1.49	$ 1.49
Potentiometer	10k ohm	1	$ 1.79	$ 1.79
Resistor	10 ohm	7	$ 1.44	$ 10.08
Resistor	330 ohm	7	$ 1.44	$ 10.08
Resistor	220 ohm	1	$ 1.44	$ 1.44
Resistor	12k ohm	1	$ 1.44	$ 1.44
Music Shield	Music Instrumental Shield	1	$ 30.95	$ 30.95
Arduino	Seeeduino V3.0 Arduino Compatible board (ATmega328)	1	$ 21.00	$ 21.00
Amplifier	Stelectronics 3W Mono-Channel Amplifier	1	$ 0.91	$ 0.91
Wires	20g 25ft red/black wire	1	$ 6.27	$ 6.27
Wires	20g 6-yard wire	1	$ 7.00	$ 7.00
Solder	1 oz. roll	1	$ 5.47	$ 5.47
Micro Servo Kit	Supplied	1	$ 5.36	$ 5.36
Photoresistor	CdS	1	$ 1.00	$ 1.00
Switch	16mm illuminated push button switch	2	$ 3.00	$ 6.00
LED	Red, 3mm	3	$ 0.27	$ 0.80

LED	Green, 3mm	3	$ 0.27	$ 0.80
LED	Yellow, 3mm	2	$ 0.27	$ 0.54
9V Battery	Energizer 2-pack	1	$ 6.98	$ 6.98
Misc.				
Ball	3/4" diameter steel ball	1	$ 7.67	$ 7.67
Ball Tube	3D printed (2 hours)	1	$ 2.00	$ 2.00
Electronics Box	3D printed (4 hours)	1	$ 4.00	$ 4.00
Lion King figurines	6 pc. play set	1	$ 22.95	$ 22.95
Paint	Acrylic paint set	1	$ 8.98	$ 8.98
Total				**$ 191.72**

SECTION 5: MANUAL

Group
31

MAE 151 MUSIC BOX

The Rise of Simba

User's Manual

Table of Contents

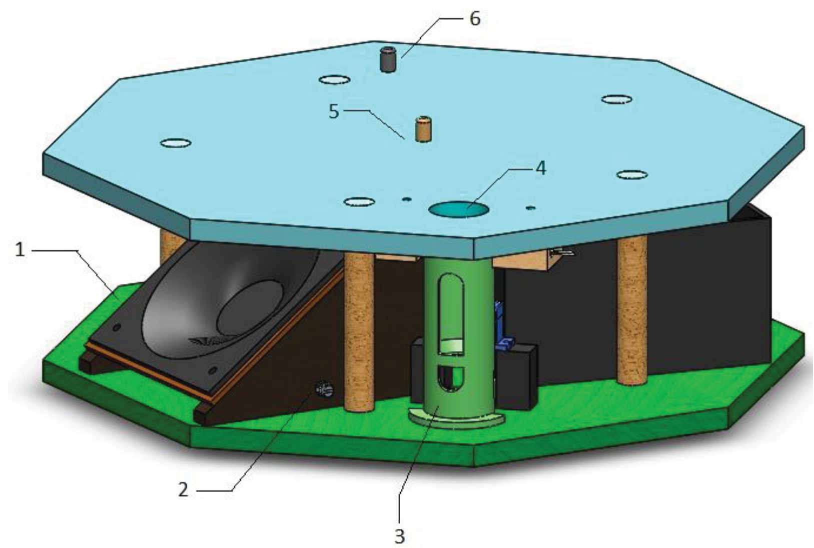
Thank You

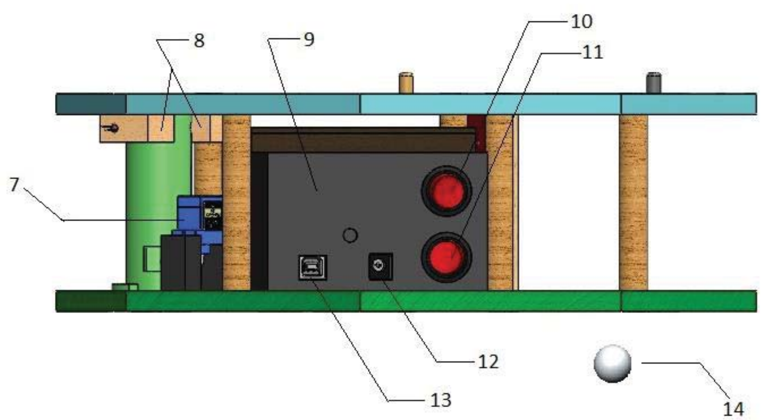
Thank you for choosing The Rise of Simba Themed Music Box. To get the most from this box, please read all instructions thoroughly and keep them where they will be read by all that use the product. Enjoy the product!

Getting to Know the Music Box

Take a few moments to familiarize yourself with the music box and its controls. You may find it helpful to bookmark this section and refer to it as you read through the rest of this manual.

THE MUSIC BOX COMPONENTS





1 Speaker
2 Volume control knob
3 Guide tube
4 Activation hole
5 Alignment pin
6 Alignment stud
7 Ball catch mechanism

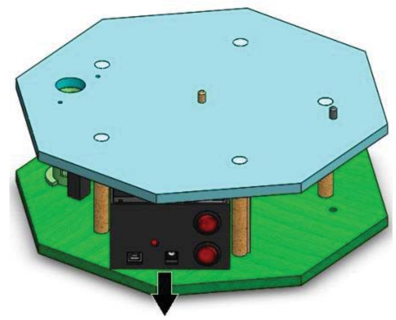
8 Ball sensing mechanism

9 Electronics container
10 Power switch
11 Mute switch
12 Power connector
13 USB connector
14 Activation ball

FIRST STEPS

INSTALLING THE BATTERY

1. Remove the electronics container. It is attached to the music box via Velcro.

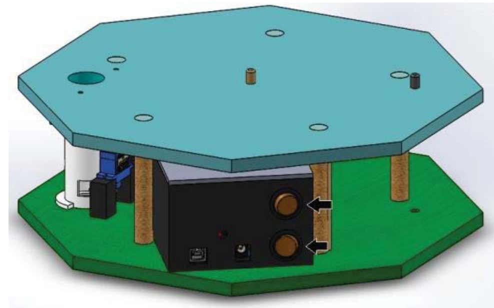


2. Remove the electronics container top cover.
It is attached to the electronics container via Velcro

2. Insert (2) 9 volt batteries into each of the battery slots shown in the figure on the right.
Attach the electronic connectors to the battery and then reverse disassembly to install.

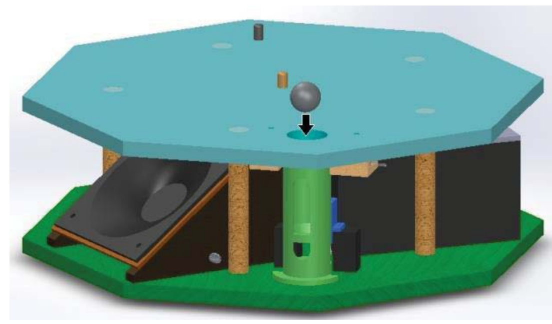
TURNING ON THE MUSIC BOX

1. Press the bottom switch to power the speaker system.
Turning the switch on will make it sit lower than if it was in the off position. The switch will not illuminate.

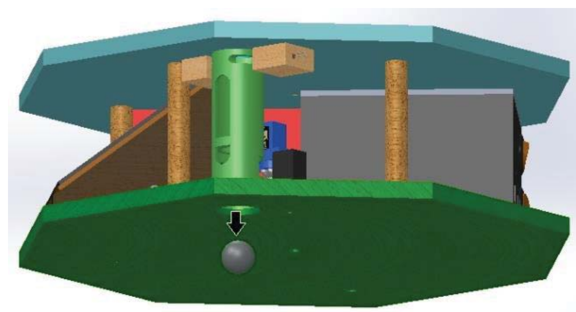


2. Press the top switch to power the rest of the electronics.
When the switch is pressed and turned on, the top switch will illuminate. If both switches are depressed with the top switch being illuminated, the entire box is on and ready to be used.

USING THE MUSIC BOX

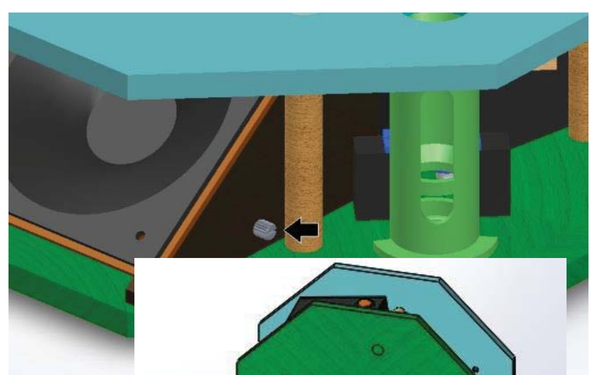


1. Place activation ball in the activation hole.
To play music from the music box, place the ball in the hole as depicted in the drawing. Music should begin playing and LEDs will flash



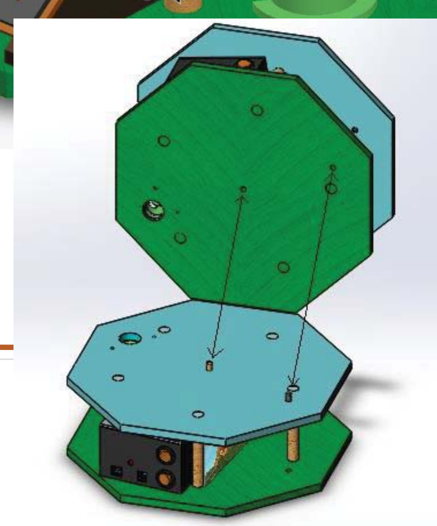
2. The ball will fall out of the bottom of the music box.
The ball that was inserted in the step above will be released from the hole shown in the drawing.

ADJUSTING THE VOLUME



1. **Locate the volume control knob on the side of the speaker box. Turn it to adjust the volume.** Turning the volume control knob counterclockwise will increase the volume. Turning the knob clockwise will decrease the volume. Turn off the bottom switch on the electronics box to mute sound completely.

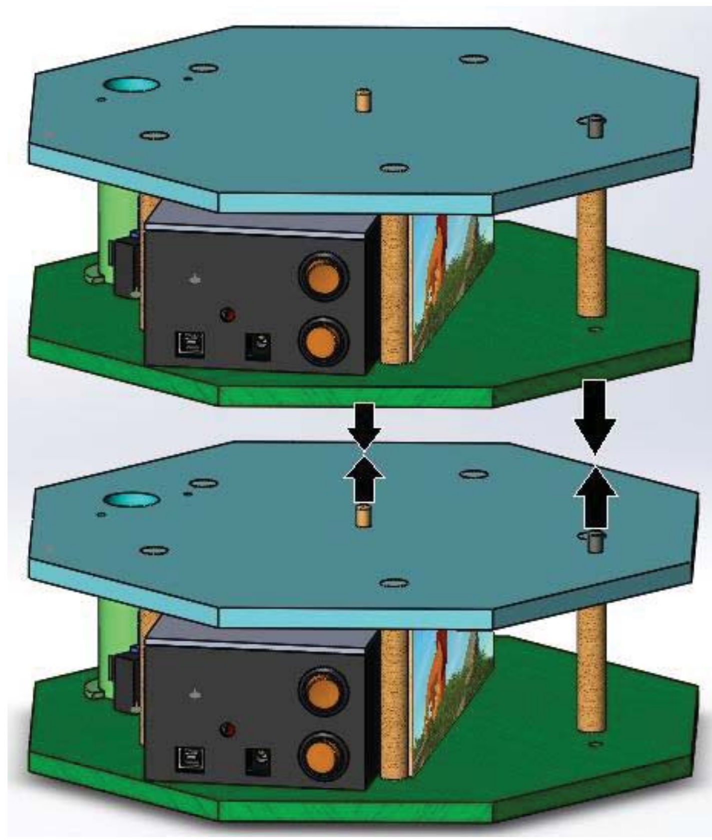
INTERLACING MULTIPLE MUSIC BOXES



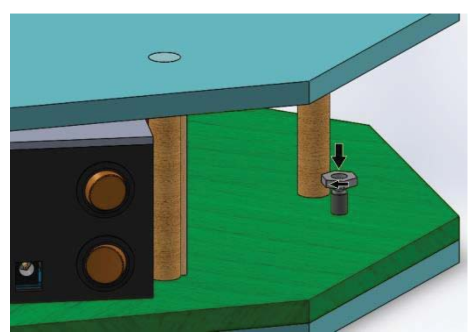
By having multiple music boxes, it is possible to mate them all together in order to play an symphony of music. The activation ball will fall through multiple boxes which will play multiple segments of a song. Follow the instructions below for more details.

1. Line up the alignment stud and alignment screw of top plate of one box with the corresponding holes on the bottom plate of the other box.
There are matching holes on the bottom plate that match the stud and screw on the top plate. Be sure to line them up for the next step.

2. Physically join the two boxes together by inserting the alignment stud and alignment screw into its corresponding holes on the other box. Mate the top and bottom plates together.
The stud and screw should go through the holes and stick out partially. The top plate of the lower boxes and the bottom plate of the top box should sit flat against each other. Proper alignment will allow the activation ball to fall through the activation slot on both boxes.



3. Lock the assembly together.
Lock the two music boxes together using the supplied nut. This will ensure the boxes stay together and not fall apart under load.



APPENDIX

SECTION 1: STATUS REPORTS

Status Report Week 2 (1/6 – 1/17)

Group Information

Kushal Shah | Thomas Van | Henry Diep | Fady Barsoum | Eric Kuo

First Two Weeks (1/6 – 1/17)

Action item	Projected Completed Date	Status	Assigned Person
Team Building / Introduction	1/10/2014	Complete	Team
Development of Website / Documentation Method	1/10/2014	Complete	Kushal Shah / Thomas Van
Outline / Idea Gathering	1/17/2014	75 %	Team
Gantt Chart	1/17/2014	Complete	Henry Diep

Next Week (1/18 – 1/24)

Action item	Due date	Status	Assigned Person
Finish the Outline	1/20/2014	N. C.	Team / Virtual Work
Two Sketch Designs	1/22/2014	N .C	Each Member
Selecting 5 Designs	1/22/2014	N.C	Team Meeting
Giving Criteria to Designs and Down selecting Matrix	1/24/2014	N.C	Team Meeting

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 3 (1/18 – 1/24)

Group Information

Kushal Shah   Thomas Van   Henry Diep   Fady Barsoum   Eric Kuo

First Two Weeks (1/18 – 1/24)

Action item	Projected Completed Date	Status	Assigned Person
Finish the Outline	1/17/2014	Complete	Team
Two Sketch Designs	1/20/2014	Complete	Team
Selecting 5 Designs	1/22/2014	Complete	Team
Giving Criteria to Designs and Down Selecting Matrix	1/22/2014	Complete	Team
CAD Design of 5 Selected Designs	1/24/2014	I. P.	Each Member

Next Week (1/24 – 1/31)

Action item	Due date	Status	Assigned Person
Select 1 Design to Fabricate	1/29/2014	N. C.	Team Meeting
Begin Looking for Stores/Vendors for Fabrication	1/29/2014	N .C	Each Member
Order Addition Parts/Supplies	1/31/2014	N.C	Team Meeting
Assign Tasks for Fabrication/Electronics	1/31/2014	N.C	Team Meeting

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 4 (1/24 – 1/31)

Group Information

Kushal Shah | Thomas Van | Henry Diep | Fady Barsoum | Eric Kuo

This Week (1/24 – 1/31)

Action item	Projected Completed Date	Status	Assigned Person
Select 1 Body Design to Fabricate	1/27/2014	Complete	Kushal, Thomas, Henry, Fady
Ball Sensor and Catch Design	1/29/2014	Complete	Team
Obtain Wood from Steve	1/29/2014	Complete	Eric
Obtain Electronics from Raymond	1/29/2014	Complete	Team
Fabrication of Body	N/A	I. P.	Eric & Henry
Electronics	N/A	I. P.	Kushal, Thomas, Fady

Next Week (1/31 – 2/7)

Action item	Due date	Status	Assigned Person
Finish Fabrication	1/29/2014	N. C.	Eric & Henry
Finish Electronics with Calculations	1/29/2014	N .C	Kushal, Thomas, Fady
Begin Assembly with Electronics	2/7/2014	N.C	Team
Test Box	2/7/2014	N.C	Team

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 5 (1/31 – 2/7)

Group Information

Kushal Shah   Thomas Van   Henry Diep   Fady Barsoum   Eric Kuo

This Week (1/31 – 2/7)

Action item	Projected Completed Date	Status	Assigned Person
Finished Body Fabrication	1/31/2014	Complete	Eric & Henry
Finished Electronics	2/5/2014	Complete	Fady, Kushal, Thomas
Obtain Speaker	2/7/2014	Complete	Team
Start Documentations	2/10/2014	I. P.	Team
Work on Amplifier sound	2/10/2014	I. P.	Kushal & Fady

Next Week (2/7 – 2/14)

Action item	Due date	Status	Assigned Person
Complete Structure	2/11/2014	N. C.	Eric, Thomas, Henry
Get Amplifier Working	2/10/2014	N .C	Kushal, Thomas, Fady
Assembly Documentation	2/10/2014	N.C	Team
Test Box	2/10/2014	N.C	Team

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 6 (2/7 – 2/14)

Group Information

Kushal Shah   Thomas Van   Henry Diep   Fady Barsoum   Eric Kuo

This Week (2/7 – 2/14)

Action item	Projected Completed Date	Status	Assigned Person
Complete Structure	2/11/2014	Complete	Eric, Thomas, Henry
Get Amplifier Working	2/10/2014	Complete	Fady, Kushal, Thomas
Assemble Documentation	2/10/2014	Complete	Team
Test Box	2/10/2014	I. P.	Team

Next Week (2/14 – 2/21)

Action item	Due date	Status	Assigned Person
Review Midterm Results	2/19/2014	N. C.	Team
Determine improvements	2/21/2014	N .C	Team
Begin redesign	2/21/2014	N.C	Team

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 7 (2/14 – 2/21)

Group Information

Kushal Shah Thomas Van Henry Diep Fady Barsoum Eric Kuo

This Week (2/14 – 2/21)

Action item	Projected Completed Date	Status	Assigned Person
Review Midterm	2/19/2014	Complete	Team
Determine Improvements	2/19/2014	Complete	Team
Begin Redesign	2/19/2014	Complete	Team

Next Week (2/21 – 2/28)

Action item	Due date	Status	Assigned Person
Finish Music Box Structure	2/24/2014	N. C.	Eric
Finish Speaker Structure	2/25/2014	N .C	Eric & Henry & Fady
Improve Sound	2/26/2014	N.C	Fady & Kushal
Paint Box	2/27/2014	N.C.	Thomas
Assemble Music Box	2/28/2014	N.C.	Team

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 8 (2/21 – 2/28)

Group Information

Kushal Shah | Thomas Van | Henry Diep | Fady Barsoum | Eric Kuo

This Week (2/21 – 2/28)

Action item	Projected Completed Date	Status	Assigned Person
Finish Box Structure	2/24/2014	Complete	Eric
Finish Speaker Structure	2/25/2014	Complete	Eric & Henry & Fady
Improve Electronics Sound	2/26/2014	Complete	Fady & Kushal
Paint Box	2/27/2014	Complete	Thomas
Put Everything Together	2/28/2014	I. P.	Team

Next Week (2/28 – 3/7)

Action item	Due date	Status	Assigned Person
Assembly Together Full Structure	3/2/2014	N. C.	Eric & Kushal
Test Electronics	3/7/2014	N .C	Team
Fix Any Errors during Testing	3/7/2014	N.C	Team

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 9 (2/28 – 3/7)

Group Information

Kushal Shah Thomas Van Henry Diep Fady Barsoum Eric Kuo

This Week (2/28 – 3/7)

Action item	Projected Completed Date	Status	Assigned Person
Assemble Box with Internals	3/7/2014	Complete	Team
Test Internals integrated with Box	3/7/2014	Complete	Kushal & Fady
Solder remaining wiring	3/7/2014	Complete	Fady & Kushal
Touch-ups on Box paint and design	3/7/2014	Complete	Thomas & Henry

Next Week (3/7 – 3/14)

Action item	Due date	Status	Assigned Person
Assemble Final Documentation	3/14/2014	N. C.	Team
Final Revision of Box	3/14/2014	N .C	Team
Begin Final Powerpoint Presentation	3/14/2014	N.C	Team

Note

None at this moment.

Concerns

None at this moment.

Status Report Week 10 (3/7 – 3/14)

Group Information

Kushal Shah   Thomas Van   Henry Diep   Fady Barsoum   Eric Kuo

This Week (3/7 – 3/14)

Action item	Projected Completed Date	Status	Assigned Person
Assemble Final Documentation	3/17/2014	I.P.	Team
Finish Missing Documentation	3/17/2014	I.P.	Team
Begin Powerpoint	3/17/2014	I.P.	Team
Final Check of box	3/17/2014	I.P.	Team

Note

None at this moment.

Concerns

None at this moment.