Project 2: Educational Traveling STEM Museum Exhibit

Project Developed by: Group #2

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Abstract

Tasked with creating a portable science museum exhibit that demonstrated a STEM-related principle or concept intended to educate high school level students, our group came up with design goals of creating an exhibit that is educational, produced sound, interactive, and visually appealing around the principles of electromagnetism. With these design goals in mind, our group built an exhibit around the concept of an electromagnetic controlled bell that swung like a pendulum and produced sound at the point of contact with the electromagnets. The basis of the exhibit was then constructed around the idea that users could create their own bell rhythm by manually controlling the electromagnets. This interactive portion of the project was intended as a mean of increasing the user's engagement to learning the educational concepts of the exhibits. Based off the results from the exhibition and analyzing both qualitative and quantitative data, we feel that our developed solution adequately performs as a portable museum exhibit and serve its educational purpose.

Table of Contents

List of Tables

List of Figures

Introduction and Background

Our group was approached by a client that was starting up a traveling museum exhibit for high school students. Their objective was to create a portable exhibit that focussed on interactive learning experiences in the science, technology, engineering, and math, fields. We were tasked with the development of a prototype for the exhibit. The problem is that there is low interest in the STEM field among teens. This is because many teens do not have the opportunity to STEM exposure in a fun and engaging environment. There are limited available designs that meet this need. The client would like prototypes designed that are educational, produced sound, interactive, and visually appealing. Our solution will be portable, include interactive components, contain a laser-cut part, and cost less than $100. From our observation at the science museum, we found that successful exhibits all demonstrated a heavy emphasis on sound for its appeal to the user and audiences. Thus with this idea in mind, our group decided on presenting the principles behind electromagnetism and magnetic law of attraction around the concept of producing sound and formulated on the idea of a electromagnetic bell. Unlike a conventional electromagnetic bell, however, we wanted to demonstrate this concept by allowing the bell to swing like a pendulum and create sound at the point of contact with the electromagnets. With this idea, our group created an exhibit that allows the user to create their own bell rhythm to increase their engagement and aid them in learning the educational material of this exhibit.

Methodology

Based on our major design goals--educational, produced sound, interactive, and visually appealing--very early on we focused the educational purpose of our project on the concept of electromagnets to demonstrate the principles of electromagnetism and magnetic attraction. Our group also decided to heavily emphasize on implementing the concept of producing sound based on our observation of engaging exhibition at the museum of science, and thus, decided to build the majority of around the concept of a conventional electromagnetic controlled bell. In order to make this concept more appealing, our group decided to add more visual to the exhibit by moving away from just magnetically controlling the clapper inside the bell to produce sound but instead magnetically control the entire metal dome and produce sound at the point of contact with the electromagnets. We decided on this concept through a rank order chart, shown in table 1, of ways for the exhibit to produce sound through a bell and primarily based the criteria of our decision on the feasibility of implementation due to time and the difficulty of implementation based on our skill set. Other than the idea of moving the clapper, this process allowed us to eliminate the idea of creating sound through a vertically hovering miniature bell due to the difficulty of implementing this concept.

Table 1: Rank Order Chart

	Stem Related	Produced Sound	Engaging/ Fun	Time Feasibility	Lowest difficulty of implementation	**Total**
Magnetic Striker	1	1	1	3	3	**9**
Bell Pendulum (move side to side)	2	3	2	2	2	**11**
Hover mini bell (vertically)	3	2	3	1	1	**10**

To create the electromagnets for the initial concept review, our group made the electromagnets using a large metal bolt wrapped in a layer of magnetic copper wire and powered it with a 5V battery pack. The testing for this demonstration allowed us to realize that in order to move the bell, a large metal dome, the current running through the magnets had to be significantly stronger. Thus for our initial concept review, we used three AA batteries connected in series to power our electromagnets and that was sufficient to attract the bell. For the final prototype, in order to further emphasize on the sound producing component of the project to increase its appeal and attention engagement aspect, our group wanted to incorporate the idea of creating rhythms out of sound produced by the bell and syncing it with songs. We believed that the implementation of music into our project would further increase the user's engagement with the learning process of our exhibit. But upon reviewing our design goals after the initial concept demonstration, we realize that the interactive portion of our project could be significantly improved and decided to abandon the idea of syncing the bell rhythm with songs. Instead, we pursued the idea of manually controlling the electromagnets to allow the users to create their own bell rhythm, and get even more involved in the learning process.

Following the idea of manual bell rhythm control, our group proceeded to generate ideas as to how the exhibit would presented. Shown in figure 1, our early sketch of the design emphasized on revealing the electromagnets and the movement of the bells to the user. Based on the sketch, we designed an SolidWorks model of the housing of the exhibit using real dimensions, this time, incorporating room for the control buttons and interior for the circuitry of the electromagnets. The SolidWorks model for the housing of the exhibit is shown in figure 2.

Figure 1: Original Design Sketch

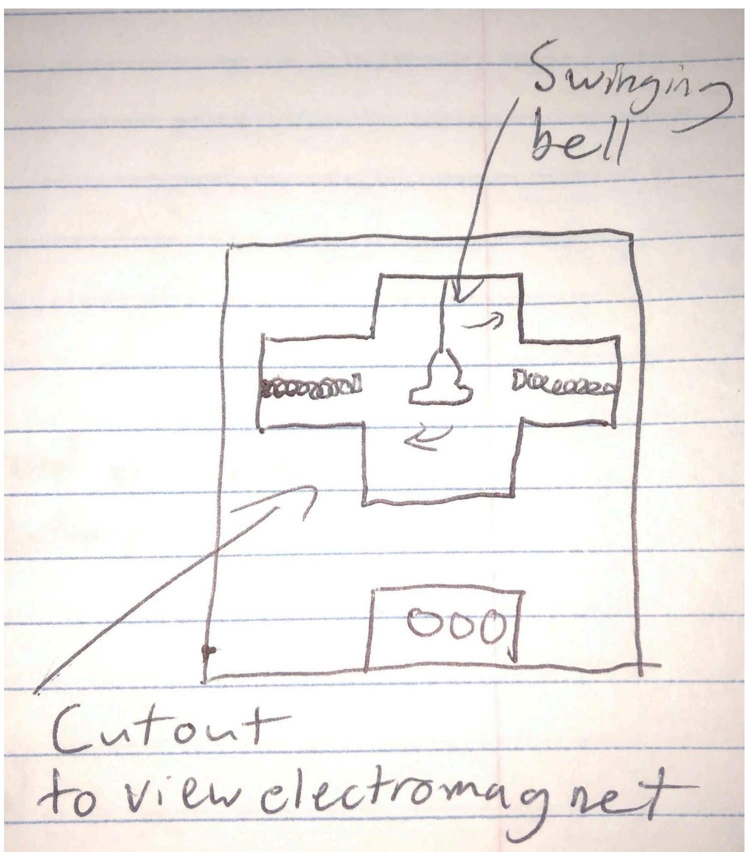
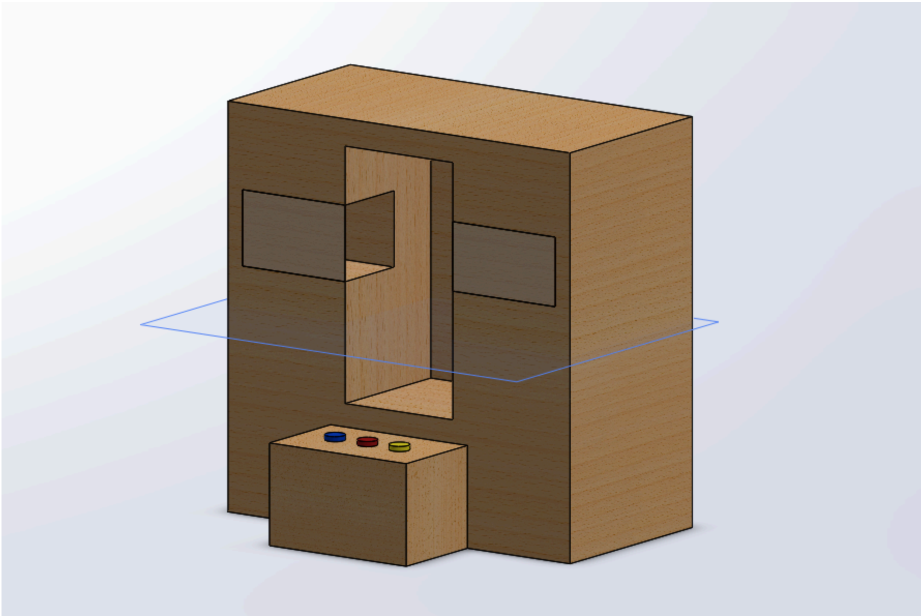
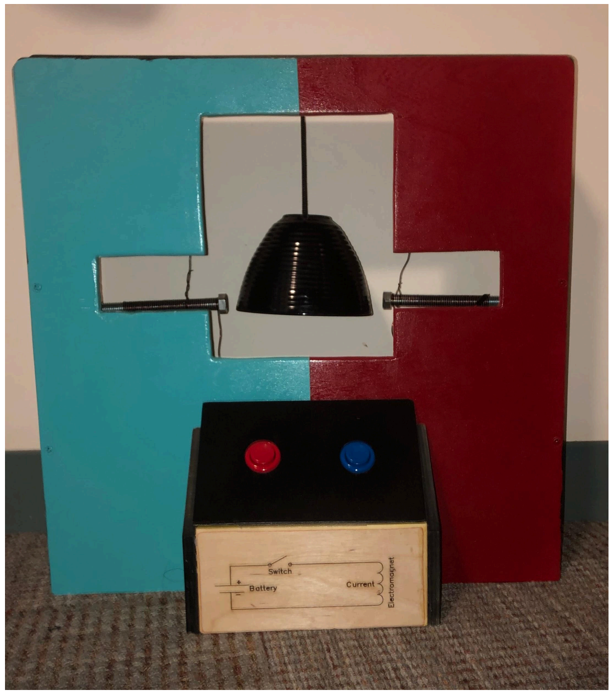


Figure 2: SolidWorks Model



We then spent several days cutting and putting together the housing and the only significant derivation from the 3D model that was made was that we did not include a back cover piece to enclose the hollow frame in order to conserve our wood piece, and resized the control box to include on two instead of three buttons. The wood construction can be seen in figure 3. While building the control box for the exhibit, we decided to engrave a simplified diagram of our circuitry on the front as an educational piece on circuitry. We initially wanted to include this detail on the tri-fold board at the exhibition but thought it would add more visual details that would keep the users more engaged on the exhibit itself.

Figure 3: Wooden Housing



Returning to the manual bell rhythm control concept, we realize the need for a larger power supply to allow the bell to swing at a quicker pace. Our group proceeded to implement a 12V AC power supply into Arduino which we could then connect to the electromagnets. However, after our repetitive attempt to use the Sparkfun motor driver--an H-Bridge--to integrate the 12V power supply to power our electromagnets, we did not manage to get Arduino to output 12V and returned to using two sets of five AA batteries connected in series, one to power each sides of the electromagnets. During testing the electromagnets proved to be strong enough to effectively attract the bell in a way that created a significant sound. As precaution for the exhibition, we prepared two new set of five AA batteries and attached it inside the housing as replacement if the ones used in testing were drained.

In preparation for the exhibition, our group agreed on the color scheme of red and blue to match the colors of our buttons, and thus we painted the housing of the exhibit and made our trifold board with this color scheme. On the trifold board we made researched key information to present on the concept behind magnets, electromagnets, ferromagnets, and the concept behind our electromagnetic bell. We then created a google survey form to get user's feedback as the last requirement for this project.

Final Design

The construction of our final prototype was based around the initial idea of creating an exhibit that was interactive but most importantly educational for the user. Our first priority was creating two function magnets. Our magnets were composed of two hex-bolts and wrapped in copper wire that was provided to us by Professor O'Connell. We then used two sets of five AA batteries as a power source to run a current through the copper wire. This created a magnetic field around the bolts making ferromagnetic objects attracted to the bolts. After we tested our magnets to ensure they would function we had to configure a user interface that would create an immediate cause and effect relationship with the user. An immediate response after the users interaction was our top priority for this portion of the exhibit. We decided to utilize two arcade buttons to turn the magnets on and off. This made it very easy to understand which magnet was being turned on at that time. The right button controlled the magnet on the right side and vice versa on the left. When the right button was hit we had a bell in the middle swing to the magnet that was turned on. This created an audio response for the user, and helped exaggerate the attraction of the magnet. With the sound created from the bell users were able to turn each magnet on or off and create their own beat.

In order to make the STEM topic of electromagnetism easier to understand we included a poster board with information pertaining to the topic. This poster had a red and blue color scheme that was chosen to replicate the color scheme of a magnet. The information we included explained the magnets that we built as well as electromagnetism in general. On the poster there was a QR code that when scanned opened up a survey to help us collect data on our project.

Overall, the importance of the user was placed over the other aspects of the project and while it made the prototype more simplistic, it delivered the information of the STEM far more effectively (Refer to Appendix B for all view angles of the project).

The cost breakdown of our final prototype can be found below in Table 2.

Table 2 : Cost Breakdown

Item	Value
Batteries	$4.99
Plywood	$26.55
Blue & Red Spray Paint	$9.68
Eye Screws	$2.29
2 Ferromagnetic Bolts	$4.00
Yellow & Black Spray Paint	$7.22
Arcade Buttons	$6.00
Total	**$60.73**

Results

At the beginning of the design process, our group identified major design objectives and constraints that we had to adhere to through the design process. The first primary design objective was to ensure that the exhibit focused on an appropriate STEM topic. It had to provide an interactive learning experience for high school students appropriate for their level of general STEM knowledge. In addition to this, the exhibit must fit on a table that measures 28 in x 26 in and be reasonably safe for use. The exhibit must contain educational material that explains the concept. The exhibit as a whole must be transportable and cost less than $100 to produce. Additional goals include automatic data collection, preloaded song selections, and aesthetic appeal.

The entire exhibit was focused on the STEM topics of electricity, magnetism, and circuits. Electricity and circuits are an integral part of the exhibit, enabling the electromagnet to work.

There was a specific focus on batteries running in series as well as open and closed circuits. The relationship between electricity and magnetism is emphasized in the creation of the electromagnetic bell as well as the information discussed on the poster board. The primary takeaway shown by survey data is that people learned about how running a current through a wire wrapped around a ferromagnetic object creates a magnetic field.

Interactiveness was also a high priority goal in our design process. We incorporated buttons into our design to create an interactive exhibit but decided that buttons on a breadboard were not user friendly and would hinder interaction. Thus, we replaced the buttons with arcade buttons mounted on a wooden console. Thus allowed for more robust interaction without damaging the product and prolonging the time during which the exhibit can function.

A design requirement was that the exhibit had to fit on top of a 28 in x 26 in table and remain safe for users. The surface of our box measured 6 in x 20 in, well within the constraint. The total dimensions of our box were 6 in x 20 in x 20 in (height of 20 in). Despite the small size, safety remained a top concern. Sharp corners were sanded down and the box was built out of non-splinter wood. All circuits and batteries were contained inside the box and console, out of the reach of those interacting with the exhibit. Wires were not exposed and all wires were insulated just in case someone managed to touch them.

Educational material was included on the tri-fold poster board. On the poster board, we included information about general earth magnets, ferromagnetism, diamagnetism, and paramagnetism. The poster board also contained information relating to electrostatic forces and the attraction between negatively charged poles. More directly related to the exhibit, the display also explained how electromagnets are created by wrapping wire around ferromagnetic objects and running current through it.

The project as a whole cost $60.73, well under the constraint of $100. It did not meet our goal of automatic data collection, nor did we manage to incorporate preloaded songs. That said, we did receive overwhelming positive comments about the aesthetic appeal of our exhibit.

Discussion

Our exhibit met all design requirements as well as some of our personal goals and objectives. Our project's size was well within the bounds of what was allowed while also large enough for visitors to interact with it effectively. It incorporated elements of electricity, magnetism, and circuitry and synthesized them into an interactive display with visual and audible outputs. Measures were taken to ensure the safety of all users, meaning that corners were sanded, the wood was splinterless, and all circuits were concealed within the box. Wires were insulated and ends were covered with electrical tape. Aesthetic elements of our exhibit were met with praise during the actual exhibition, particularly the color scheme and the use of arcade buttons with colors contrasting with their respective sides. The bell made a clear resonating sound when struck by the electromagnet.

On the other hand, our final prototype did fall short on some of our personal objectives. We failed to meet the bonus objective of automated data collection. Due to hardware breaking down, we were unable to incorporate Arduino and MATLAB into our project. This also resulted in the inability to play songs as we had originally planned. We were forced to redesign our project, replacing the complex Arduino circuit with simple arcade button connections. In doing so, we also replaced the 12V power supply with batteries in series. All things considered, the exhibit was a success and proved educational and interesting based on the reactions of the users.

Conclusion

The performance of our final design met all necessary project requirements for the museum exhibit. The user was able to control the motion of the bell with tactile arcade buttons. The exhibit was easily transported from the storage location to the exhibition location. The design included a laser cut circuit diagram that served as a educational diagram and the housing for the button console. Additionally, the project cost $60.73, under the maximum total cost of $100.

In addition to the necessary requirements, our exhibit met the client's objectives relating to interactivity, user engagement, education, and user enjoyment. The results from the google survey that was prominently placed on our poster confirm this (See Appendix A). Out of the 62 users who interacted with our prototype, 11 users took our survey. The results were overwhelmingly positive and we were able to conclude that people were able to learn from our exhibit. During this project we developed skills that included planning projects ahead of time and sticking to a timeline leaving room for errors in the project. In addition, we enhanced our teamwork skills and were able to work with different types of individuals. The topic we focused on “Electromagnetism” was able to show each of us how to make an electromagnet and teach us basic circuitry. In future projects we will be sure to learn from our past experience and aim to plan early, communicate often, and leave extra time for improvement.

Future Work

Given more time on this project we plan to work on 3 successive goals. The most important aspect of the project is the interactive buttons. Without a consistent power source the bell will cease to operate. Currently, our design runs off of battery power. The next goal is to implement a 12 Volt power supply with Arduino using transistors to overcome the 5 Volt maximum of the Redboard. During the design phase of the electromagnet we originally sought to use an H-Bridge motor driver to control the two magnets. After facing numerous obstacles we ended up reverting to battery power due to a time constraint. If the Arduino was successfully powered using a constant power supply, the next step would be to record user input manually with a Matlab GUI along with Sparkfun. Once Matlab was incorporated the third goal of the group would be working toward music syncopation. If the time that each magnet was on was controlled by Arduino, with enough testing, the tempo of the bell could be controlled. By syncing the tempo of the bell with the beat of the users selected song, our exhibit would be much more engaging.

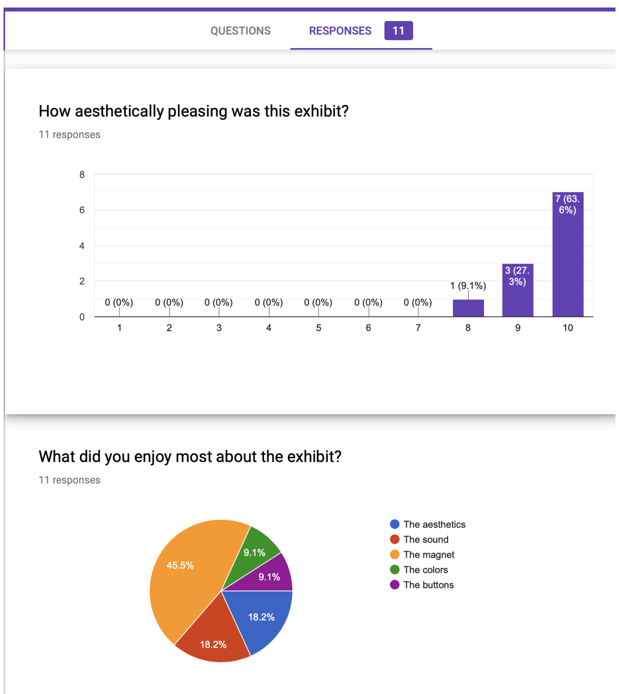
References

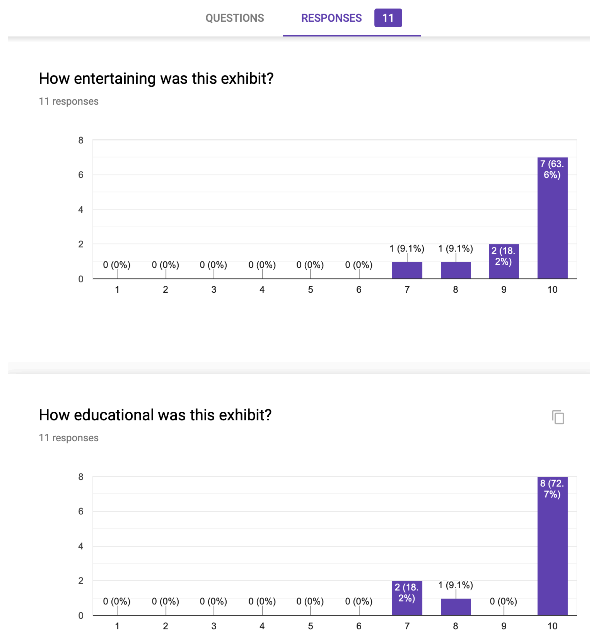
1. Brain, Marshall, and Lance Looper. “How Electromagnets Work.” *HowStuffWorks Science*, HowStuffWorks, 1 Apr. 2000, science.howstuffworks.com/electromagnet2.htm.

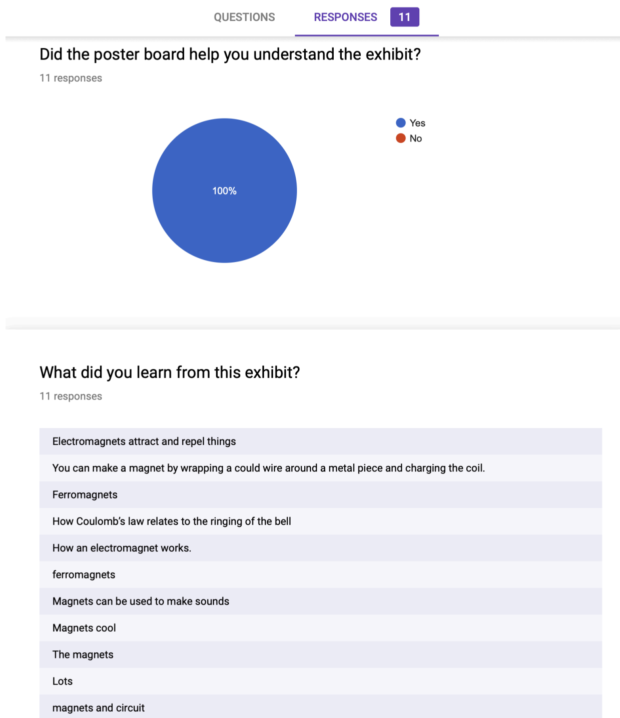
2. Koberlein, Brian. “Understanding Quantum Mechanics: What Is Electromagnetism?” *Futurism*, Futurism, 6 June 2016, futurism.com/understanding-quantum-mechanics-what-is-electromagnetism.

Appendices

Appendix A: The QR Code Survey

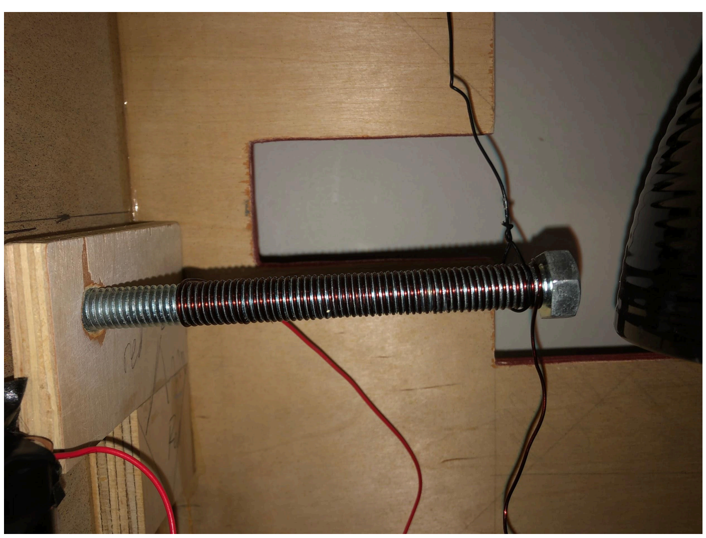




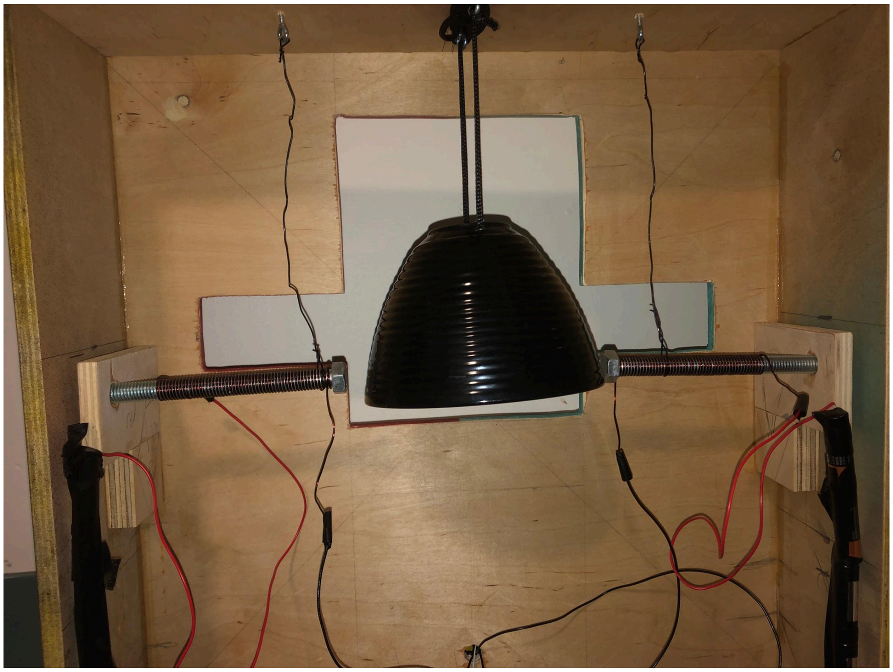


Appendix B: All views of Prototype

- **Electromagnet View**



- **Backside of Housing (Hidden to Users by Posterboard)**



- **Side View**

- **Front View**