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Constructing an Electromagnetic Horn

An electromagnetic horn is a device that produces a horn-sound, and it essentially operates like an automobile horn. But how does an automobile horn work? With one press, the car horn immediately produces a sound, but a large amount of current is generated by the horn in this process. There is a lot of physics behind the operation of an automobile horn. When a driver presses the horn, an electromagnetic coil applies current to an internal flexible metal diaphragm, causing it to move towards the coil. When the flexible metal diaphragm is attracted very closely to the electromagnetic coil, the current that was applied to the diaphragm is stopped, and the metal diaphragm is released. After the flexible metal diaphragm is released, it bounces back to its original position. This movement causes vibrations in the air around the metal diaphragm. This process of the metal diaphragm being pulled towards the electromagnetic coil and then the diaphragm bouncing back to its initial position is repeated, and it is a very quick oscillation. It is this quick oscillation of the flexible metal diaphragm that produces a horn sound in an automobile. Another interesting fact about the operation of an automobile horn is that the tone of the horn sound produced varies depending on the type of automobile. For example, the horn in compact cars such as an SUV produces a sound very different from larger cars. The reason behind this can be explained using physics as well. The reason that larger cars produce a horn sound that is much deeper and fuller in comparison to smaller cars is because larger cars have larger metal diaphragms and therefore, more powerful electromagnets (Arana 2011).

Constructing a device that operates similar to an automobile horn is the goal of this project. In order to build an electromagnetic horn (a device that works much like an automobile horn), it is necessary to clearly understand several key concepts in physics. Two such concepts are electromagnetism and electric circuits. The construction of an electromagnetic horn involves the understanding of electromagnetism and electric circuits because otherwise, the mechanism by which the electromagnetic horn produces a horn sound will not be clearly understood. One of the components of an electromagnetic horn is the use of a metal diaphragm. But why is it important that a metal diaphragm be used in the construction? This is where the concept of resistivity comes into play. "Resistivity of a material is the ratio of the magnitudes of electric field and current density" (Young and Freedman 2008). As the resistivity of a material increases, the current density that is caused by an electric field decreases. For an electromagnetic horn to effectively perform its function, the diaphragm must be a good conductor. A metal diaphragm is used in the construction of an electromagnetic horn because metals have very small resistivity, and are thereby very good conductors. An electric circuit is another very important component of an electromagnetic horn. Ohm's law is a very key concept in the area of electric circuits. Ohm's law demonstrates the relationship between voltage, current, and resistance (V=IR). This relationship helps one understand how an electric circuit works, and how manipulating one of the components of Ohm's law will have a direct effect on another component. For example, increasing the voltage supplied to an electric circuit will increase the amount of current running through the electric circuit. A battery acts as the source of voltage in order for current to run through the electric circuit (Bleaney 1976). It is important to be careful and precise in the building of an electric circuit for the electromagnetic horn as a break in the electric circuit will not only cause current to dissipate but will also cause the electromagnetic horn to not function properly.

In order to verify that the electric circuit for the electromagnetic horn is functioning properly, several electrical instruments can be applied. One such instrument is the ammeter. An ammeter is used to measure current in a circuit. It is important to make sure that current is passing through the electric circuit because it plays a crucial role in the functionality of the electromagnetic horn. A voltmeter can be used to measure the potential difference between two points in an electric circuit. A multi-meter would be a helpful tool in the construction of an electromagnetic horn because it is an instrument that can be used to measure voltage, current, and resistance (Stewart 2011).

Besides electric circuits, electromagnetism is the other key physical concept involved in the construction of an electromagnetic horn. The electromagnet is one of the most important aspects of an electromagnetic horn. Basically, in this project, insulated magnet wire was wound around a screw, which functioned as an electromagnet. This project is centered on the magnetic field that is created by the electromagnet, and which exerts a force that pulls the metal diaphragm towards the electromagnet. The magnetic field produced by the electromagnetic coil can be amplified by winding more turns of the coil. In this way, the electromagnet required for the electromagnetic horn can be compared to a solenoid. For instance, in order to have a solenoid that produces a strong magnetic field, the solenoid needs to be wound with more turns. Also, as in a solenoid, it is important for the electromagnetic coil to be wound in the same direction. This is critical because the “individual field contributions have to add together” (Dart 1966).

Finally, the type of screw that is used in this project is also important. Ferromagnetism occurs in some materials such as iron, cobalt, and nickel. For the screw, which acts as an electromagnet, it is important that one use a screw made out of an iron core. This is because ferromagnets typically produce a large amount of magnetic field “for a small applied field” (Stewart 2011). Furthermore, the relative permeability of ferromagnetic materials such as iron makes it ideal to use for electromagnets (Cullwick 1966).

There is a specific method that was followed in the construction of the electromagnetic horn. The main materials for the construction of this electromagnetic horn were two screws (the one for the electromagnet was made out of stainless steel as pure iron screws are not common commercially and the other screw was just an ordinary metal screw), insulated 23 or 24-gauge magnet wire, several sawed wooden boards, an empty metal can, a 9-volt alkaline battery, and a toggle switch. One of the most important components of this project is the empty metal can. The dimensions of the sawed wooden boards should be based on the size of the empty metal can, which will function as the metal diaphragm. The method that will be described will be based on the diagram on page 6 (depicting a rough sketch of the electromagnetic horn). Wooden board C is the base of the electromagnetic horn. A power driller was used to drill holes in wooden boards E and F. Wood glue was used to glue down wooden board F on top of the wooden board C as depicted on the page 6. A small wooden piece (G) was glued down on top of the other end of wooden board C. Board E was first glued down on top of D (on the end of Board D). Then this combination of Boards D and E wass glued on top of the small wooden board G. The stainless steel screw was fit through the hole drilled in Board F. The smaller ordinary metal screw was fit through the hole drilled into Board E. However, before drilling the holes, any paint that is coated on the surface of the metal can needs to be scraped off as the paint could potentially reduce the conductivity of current. It was verified that the screws fit through E and F were level to each other. This is very crucial for the functionality of the electromagnetic horn. A metal can (Campbell's tomato soup can with a diameter of 3.75 in.) was taped down to wooden board C. This is very crucial for the functionality of the electromagnetic horn. The insulation on the wires was taken off to reveal the copper wire inside. The copper wire (magnet wire) was carefully wound into a coil on the screw attached to Board F. The coil was wounded as tightly as possible with a considerable number of turns in an attempt to make the electromagnet stronger. After tightly winding the coil around the screw in wooden board F, it has to be made sure that both ends of the magnet wire coiled around the screw are left hanging (there should a considerable length of wire hanging off both ends of the electromagnetic coil. It was also verified that the screw attached to wooden board E touches the bottom of the empty metal can. The screw attached to wooden board F should be very close to the bottom of the empty metal can, however, it cannot touch the bottom of the can. One free end of the coil wound around the screw in Board F was attached to a terminal of the toggle switch. A short of length of magnet wire was then cut and one end of the wire was wound around the second terminal of the toggle switch. The other end of the short length of wire that was cut was wound around one terminal of a 9-volt alkaline battery. The wire can be held in place using alligator clips. Another length of magnet wire was cut. Once again the ends of the magnet wire were stripped of the insulation and sanded. One end of the magnet wire was wound around the head of the screw attached to wooden board E, while the other end is connected to the second terminal of the 9V alkaline battery. It is important the ends of the wire wound around the toggle switch terminals and the battery terminals be stripped of the insulation and be sanded using sandpaper, however, it is not necessary that the rest of the magnet wire be stripped of insulation (except for the coil wound around the screw attached to the wooden board F as this will act as an electromagnet). Finally the other free end hanging off of the electromagnetic coil is taped down to the inside of the metal can (Carusella 2008). Now, the construction of the electromagnetic horn is essentially complete. The toggle switch needs to be turned on and this should cause the empty metal can to produce a horn-like sound.

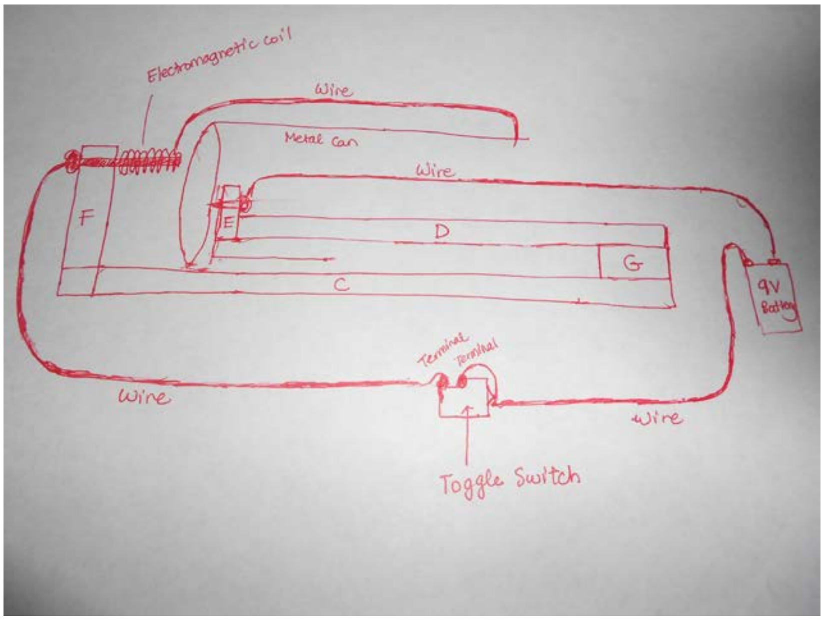

Figure 1: General diagram of electromagnetic horn

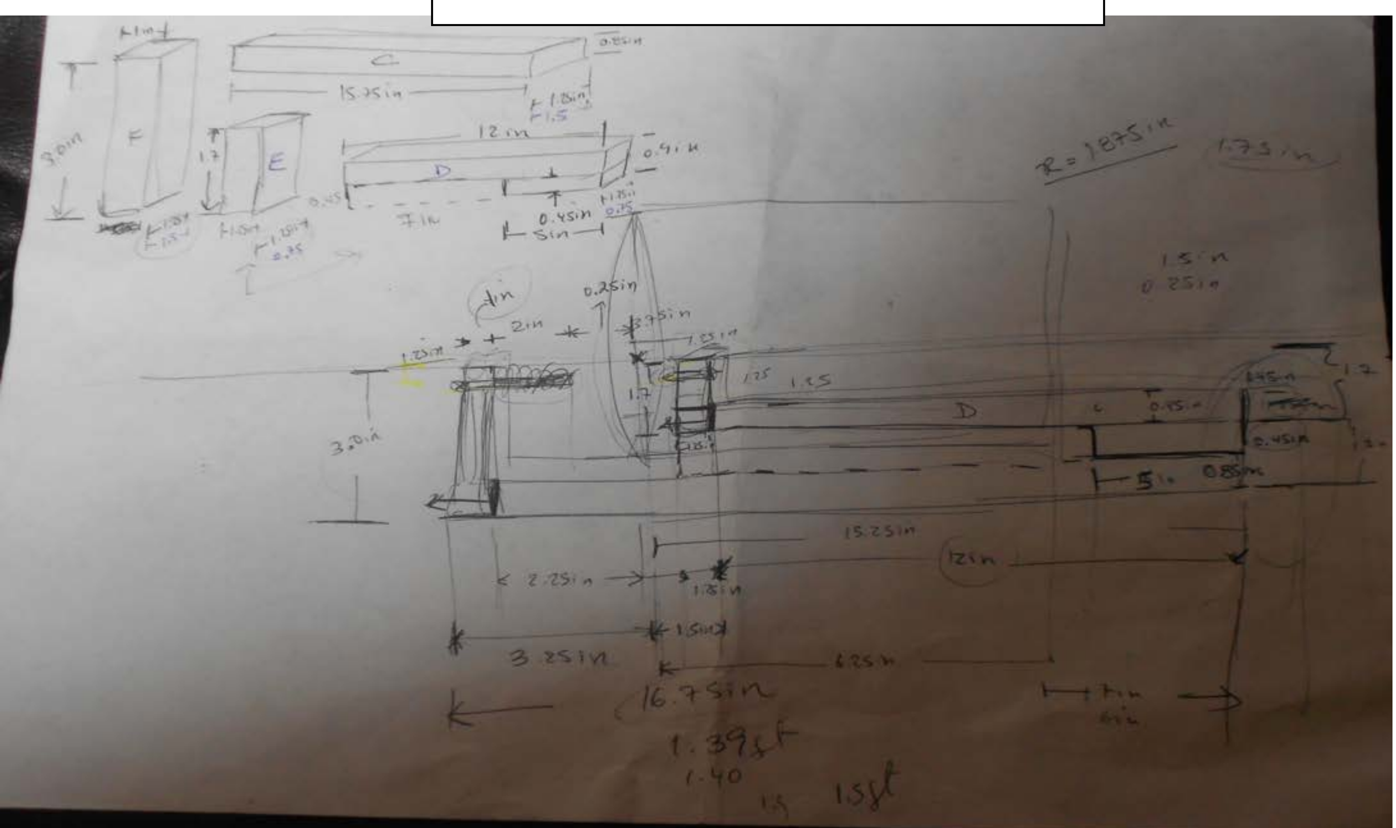

Figure 2: Detailed Sketch with dimensions

Once again, there is a lot of physics behind the operation of the constructed electromagnetic horn. When the toggle switch is turned on, the electric circuit is completed. This causes the electromagnetic coil (the coil wound around the screw in wooden board F) to act as an electromagnet. The magnetic field produced by the electromagnet exerts an attractive force on the bottom of the metal can, causing it to pull away from the screw in wooden board E. The pulling away of the empty metal can from the screw attached to wooden board E causes a break in the electric circuit. After the electric circuit is broken, the coil wound around the screw in wooden board F does not act as an electromagnet any longer. This results in the empty metal can bouncing back to its original position where it once again comes into contact with the screw attached to wooden board E and the electric circuit is completed again. And this process repeats itself. The movement of the empty metal can in this process causes the bottom of the metal can to vibrate, and it is the vibrations of the metal can bottom the produces a horn-like sound.

Having discussed the method of construction of the electromagnetic horn for this project, the electromagnetic horn that was constructed did not produce a horn-like sound. When the toggle switch was turned on, the empty metal can only produced a very minute sound that was not clearly audible and did not resemble a horn. However, troubleshooting is a step in many construction projects and hence the design of the device does have to be adjusted. Hence, various parameters of the electromagnetic horn were investigated in order to determine why the electromagnetic horn was not functioning as it should. First, the electromagnetic coil was unwound and then wound with more turns because it is possible that the magnetic field produced by the electromagnetic coil was not strong enough to pull the empty metal can towards itself. Therefore, winding the coil around more turns should strengthen the magnetic field. But, this change did not result in any change in the sound produced by the metal can. Another parameter that was measured was the diameter of the metal can used. A second soup can with a diameter of 3 inches was used. The toggle switch was once again turned on to complete the circuit, however, the metal can still did not produce a clearly distinguishable sound resembling a horn. A third parameter measured was the flexibility of the metal can used. As soup cans tend to be quite rigid, an aluminum soda can was used as it is much more flexible than a soup can. The aluminum soda can had a diameter of 2.5 inches and was lighter than the soups cans that were used previously. The flexibility and lightness of the metal can is a critical parameter because it is possible that too much magnetic force is required by the electromagnet to pull the rigid and heavier soup can towards itself. However, changing the metal soup can to an aluminum soda can did not cause the can to produce the expected horn sound. A final parameter that was investigated was the voltage supplied to the electric circuit. A 9V alkaline battery was the voltage source but it is possible that this voltage is not enough to cause a significant amount of current to pass through the circuit and allow the process of the magnetization of the coil and the movement of the empty metal can to occur. Hence, another 9V alkaline battery (or in total 18 volts) was added to the electric circuit. Even this change in the amount of voltage supplied to the electric circuit did not appear to improve the functionality of the electromagnetic horn. A multi-meter was used to check that current was actually passing through the electric circuit, because if there is no current passing through the electric circuit, then it is clear why the electromagnetic horn is unable to function. At first, the multi-meter could not detect any current passing through the electric circuit. So the electrical connections were checked to make sure there were no breaks in the electric circuit. Finally, after some adjustments, the multi-meter did show that current was passing through the electric circuit and hence that the electric circuit was complete. However, the device was still not producing the expected horn-like sound or any clear sound. The constructed electromagnetic horn was then connected to a filtered power supply device to see if greatly increasing the power supply would cause the metal can to move towards the electromagnet and result in the vibrations the metal can bottom to produce a horn-like sound. There was a minute sound produced by the metal can but it did not resemble a horn sound. An attempt was made to replace the metal can with a flat aluminum sheet as it is not rigid and is very flexible. However, the sheet was too soft a material and resulted in the screw (serving as the electromagnet) actually welding into the aluminum sheet (as the screw did have a sharp point).

There are several reasons to explain why the constructed electromagnetic horn did not function as it should have. One possible reason is that the number of turns of the electromagnetic coil was still not enough to create a strong magnetic field that would pull the empty metal can towards itself. Hence, an improvement that could be made is to first test the magnetism (magnetization) of the electromagnetic coil after winding more turns on the coil, as the functionality of the electromagnetic coil plays a key role in the functionality of the entire electromagnetic horn. Another reason the constructed electromagnetic horn could have not worked is because the metal cans used were not flexible or light enough. Hence, a great amount of force would be required the move the metal can. An improvement that could be made to solve this problem is to use a flat, hard, and flexible metal to serve as the metal diaphragm. This would definitely allow the electromagnet to more easily exert a force on the metal and allow it to more easily move, and thereby result in the vibration of the metal and a production of a horn-like sound. The physical concepts of electromagnetism and electric circuits ensure that the construction of a functioning electromagnetic horn is definitely possible. In the future, some adjustments need to be made to the methodology used this project (considering the possible reasons the constructed electromagnetic horn did not function), and this should allow for the successful construction of an electromagnetic horn.

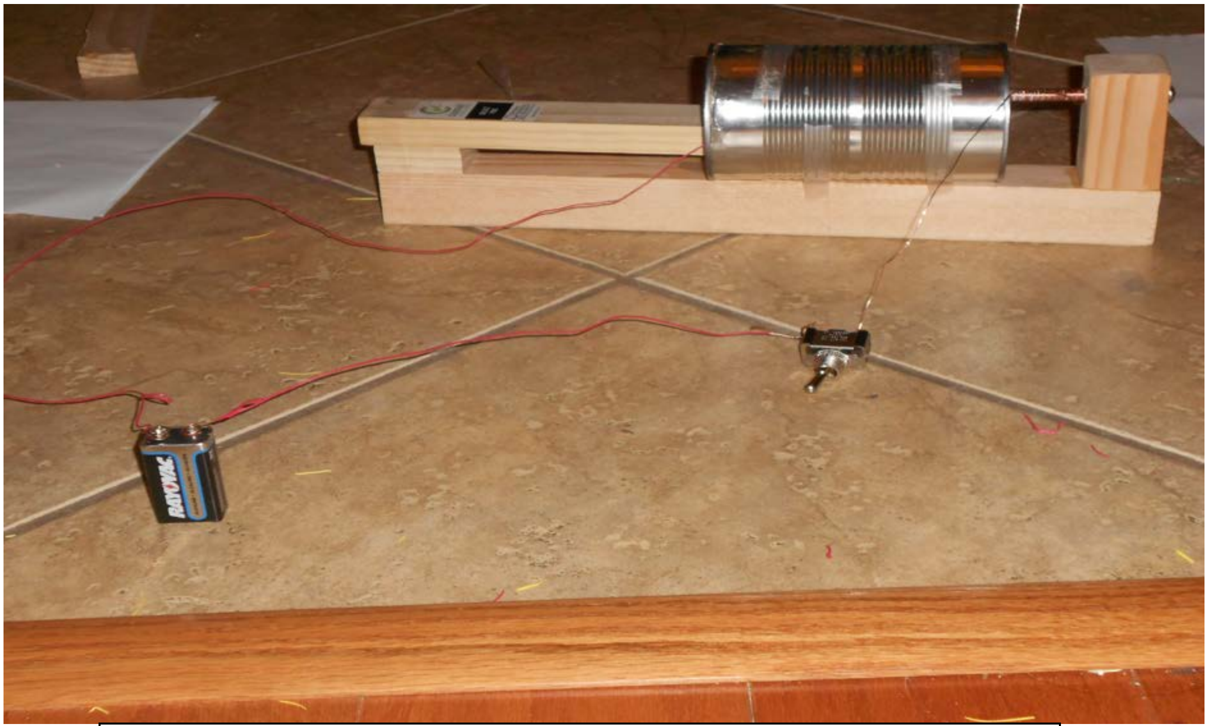

Figure 3: Initial construction using metal soup can of diameter 3.75 inches and one 9V alkaline battery

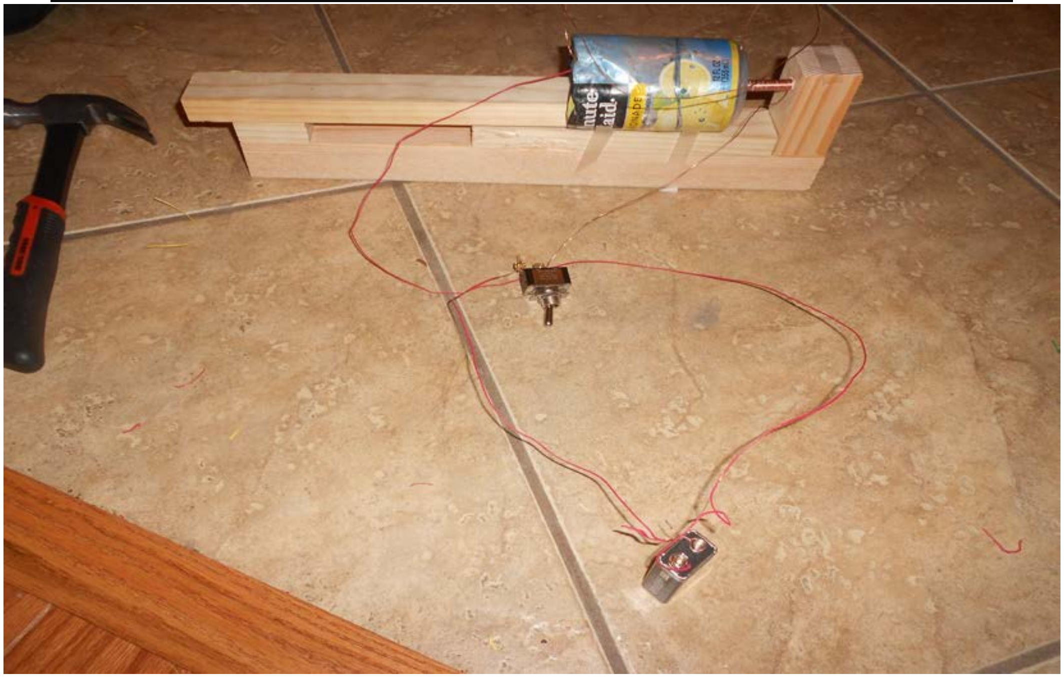

Figure 4: Second trial using aluminum soda can of diameter 2.5 inches and one 9V alkaline battery voltage source

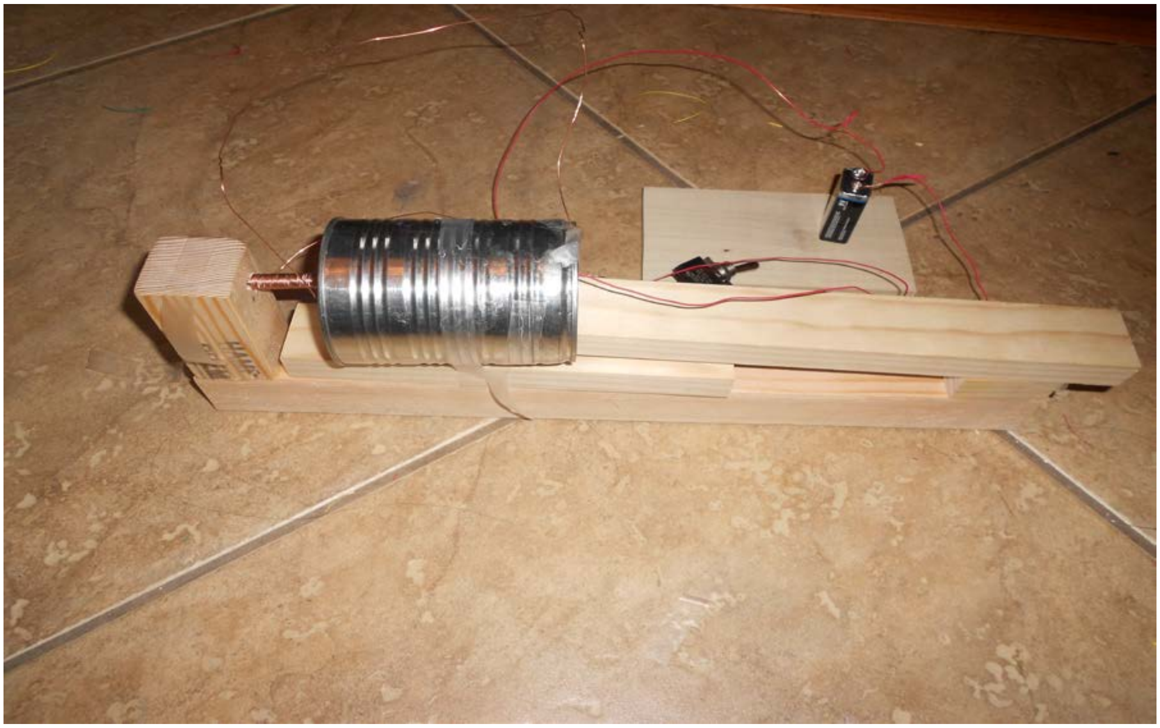

Figure 5: Trial 3 using a metal soup can of diameter 3 inches and a 9V alkaline battery

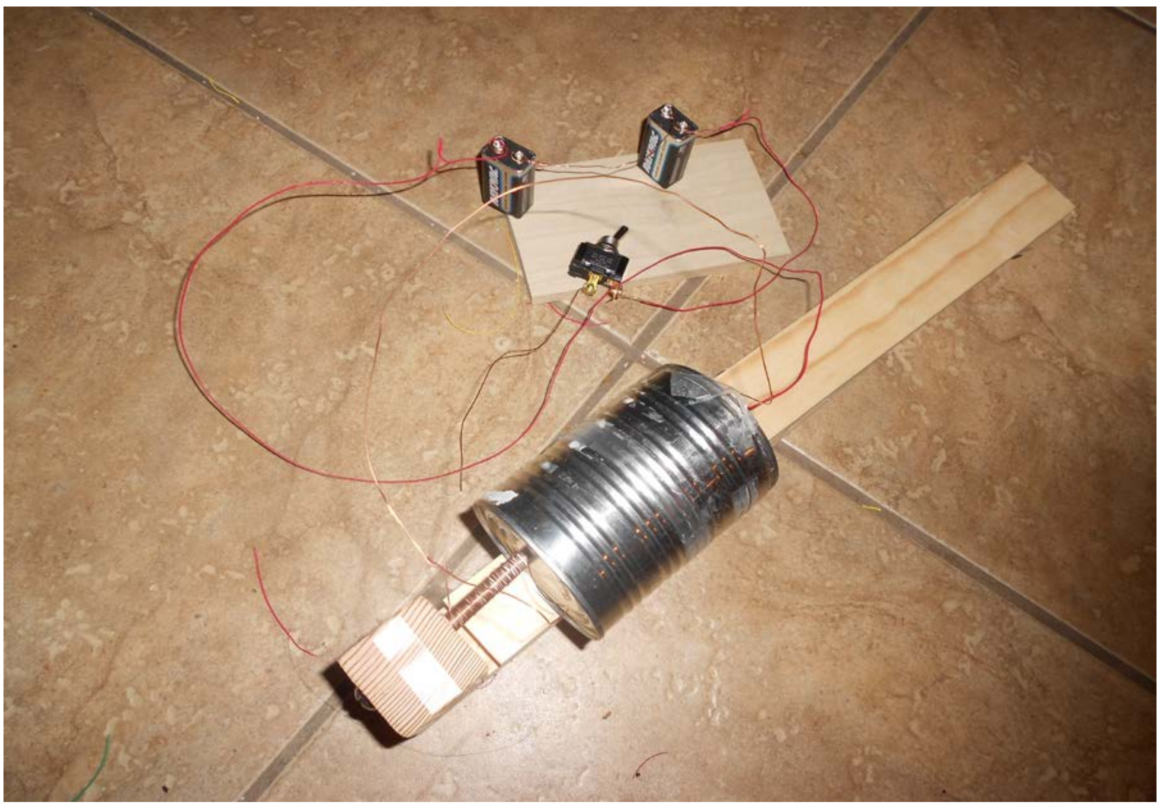

Figure 6: Trial 4 using a metal soup can of 3 inches and two 9V alkaline batteries (total of 18V)

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