Elements of the basic Coil Gun

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Throughout history man has contemplated the driving force of the universe. From micro scale collisions of subatomic particles to macro scale interactions between celestial bodies, man has attempted to explain the reasons for these interactions and understand why these things are possible. Years of intense research and billions of calculations have led scientist to realize the universe is governed by four fundamental forces, these being the: strong, weak, gravitational and electromagnetic. Though all fascinating in their own regard, our project focuses on merely the electromagnetic force. A great project to demonstrate electromagnetic forces in there simplest ways is a coilgun.

A coilgun is a device that relies upon the basic principles of electricity and magnetism to propel ferromagnetic objects at potentially high velocities. Coilguns are basically solenoids possessing electromagnetic coils which pull ferromagnetic objects to the center of coils. The energy used to produce the strong electromagnetic field from the coils is a large quantity of current. The strong magnetic field is produced by a single discharge of the large current stored in its capacitors. When the ferromagnetic object reaches the center of the coils the electromagnetic force between object and the current going through the coil ceases to exist. At this point the ferromagnetic object travels on a count of its own momentum. If the current was not turned off when the object reached the center point of the coils, the object would switch magnetic poles and oscillate in the coil. There are two main types of coilguns: single stage and multistage. A single stage coilgun, like the one made for this project, uses just one electromagnet to propel the projectile. A multistage coilgun, generally much more difficult to construct and put into action effectively, uses a series of coils or electromagnetics in a line to increase the speed of the projectile as it travels through the different stages. In his book The Electromagnet and the Electromagnetic Mechanism, Silvanus Thompson discusses the effect of a multistage coil. He explains “[By] construct[ing] in a number of separate sections of short tubes, associated together end to end, and furnished with means for turning on the electric current into any of the sections separately…attraction may be kept up along a tube of indefinite length.” This implementation could send a ferromagnetic object along a tube using only coils of wire around the tube with current turning on in the right moment. The problem with this multistage coil system is that timing is extremely crucial. If not discharged at the right time, subsequent coils in the series could in fact switch the magnetic dipole of the object thus slowing it down or moving it in the opposite direction desired.

To effectively operate a coilgun, one must be able to switch the power through the coils thus creating the electromagnetic field. The simplest to build, easiest to operate, and least effective when it comes to high velocity projecting is called “the spark gap”. The spark gap releases energy stored in capacitors into the coils when the voltage reaches certain strength. Another more effective option is using a solid state switch to release the energy when the switch is flipped manually by a human operator. The solid state switch version is more difficult to build, easy to operate, and generally yields more favorable results. The solid state switch method was used in the construction of this project.

Construction of a coilgun tests the knowledge of how electromagnetic forces actually work. The first step in the construction process was to gather all necessary materials for a coilgun. These included: ten to fifteen flash cameras, a couple of D-cell batteries, a pen, a long piece (about ten to fifteen feet to be sure) of small magnet wire or small copper wire, wood, cordless drill, solder and solder gun, coat hanger, clear scotch tape, two switches, electrical tape, a D-cell battery holder, and insulated wire. With the helpful step by step process provided by Matt Hack and Marcus, a brave soul, and a pair of careful hands, the construction began. First the flash disposable cameras were carefully taken apart. To disassemble the cameras, the capacitors were de-soldered from the circuit board. In this step being extremely careful was crucial. Some of the capacitors in the cameras were still charged, a fact we learned the difficult way…..OUCH! Once the capacitor was disconnected, it was discharged by either slowly discharging over a light or a resistor, or the quick and dirty way, by grounding the two ends using a screwdriver. This process was repeated for all the cameras. Along with all the capacitors, 11 in total, a single circuit board was harvested from the cameras since that is all the build called for. Next we soldered all the capacitors in a parallel circuit to create a large capacitor bank. This bank was then soldered to the circuit board. After the core of the system was in place a charging switch was connected to the circuit board using insulated wire. We then mounted two metal connectors to a wooden holder and wired them to the chip. These connectors would pass the charge from the battery, in the end a standard D-cell, to the capacitors. We then de-constructed a pen using the hollow component housing as a barrel for the gun. Next came the crucial, and difficult, process of wrapping the coils around the barrel. To make the process easier and faster, we developed a creative way to wrap the coils. Using the idea of a lathe, we carefully inserted the end of the pen into the mouth of a cordless drill being sure not to deform the pen in any way. We then taped the long strand of magnet wire (small copper wire) about a centimeter from the one end of the tube leaving a two inch tail of wire. Direction of the coils does not matter as long as all the coils are wrapped in the same direction. With the drill turning slowly we guided the wire away from the end of the tube keeping the wire wrapped as tightly as we could creating a coil approximately an in and a half in length. This layer was covered with a thin layer of scotch tape after which proceeded to wrap the wire going back towards the opposite end of the tube. This process was repeated for four layers. We then wired the coil in series with another switch and the capacitor bank. Finally we constructed a wooden case to hold all the components of the coilgun. The switches were mounted on the side of the box, while the guts of the gun were inside and the muzzle was mounted on the top of the box. For safety reasons we insulated all of the potentially dangerous components with electrical tape. The ferromagnetic projectile was constructed from a half inch length piece of a metal coat hanger. We labeled the switches and the construction of the coilgun was complete.

Now came the testing. We tested our coilgun to see if we had made a monstrosity of a gun, but to our displeasure we had made a pretty weak gun. Our coilgun shoots four to five feet on a charge of approximately thirty seconds. If we charge it for longer it might go further due to increase in current resulting in the production of a stronger electromagnetic field. Although we were slightly disappointed at the lacking range of our coilgun, we felt great because we used our knowledge of physics to construct a working projectile launcher out of disposable flash camera components.

Table 1: Data taken for calculating muzzle velocity of the coilgun.

Height	0.5461m
Average Range	1.51m

To calculate the muzzle velocity the gun was put on a stand half meter off the ground with the barrel parallel to the ground. The coilgun was charged for thirty seconds each launch and the range was recorded. The average range was found to be approximately one and half meters. Using two dimensional kinematics equations the muzzle velocity can be found.

Figure 1: Calculation of muzzle velocity.

$V_o = \text{Range}/\sqrt{(2h/g)}$

$V_o = 1.51/\sqrt{(2(0.5461)/9.81)}$

$V_o = 4.525$ m/s

For a thirty second charge from a D-cell battery our coilgun will fire a small piece of coat hanger at four and half meters a second.

Figure 2: A snapshot of our coilgun from the top. The barrel is at the very top of the picture and is not shown very well being slightly cut off.

References

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