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University Physics II

Lab Section 4

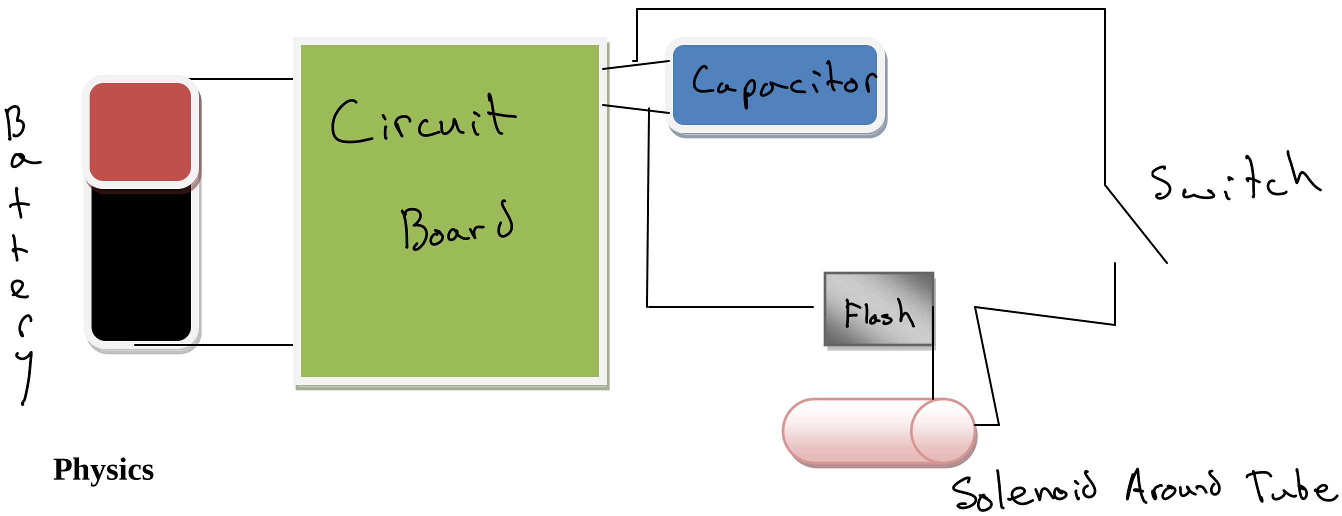
# Coil Cannon

## Introduction

The coil gun represents many of the essential concepts in physics, especially kinematic, energy, magnetic and electrical currents. These concepts explain the operation and the efficiency of the project. The coil basically consists of a coil warped around a hollow insulating tube (a solenoid) attached to a fast discharging capacitor which is connected to a power source (battery). This causes the coil to create a magnetic field from the moving electrical charge through the solenoid. A ferromagnetic material placed in the hollow tube will then be fired out of the tube in the direction of the induced magnetic moment (Paul). The fast discharging elements of a disposable camera body make a perfect base for the coil gun's energy source. The pulse of energy required for the flash is what is needed for the pulse of energy needed to launch the ferromagnetic material.

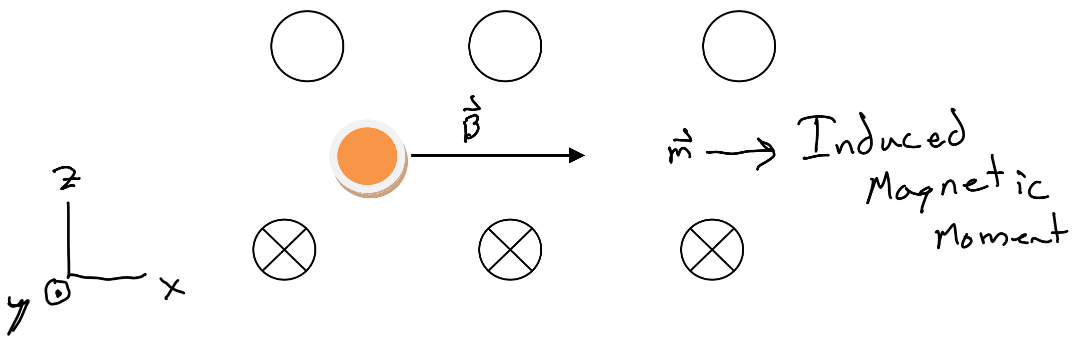
## Construction

The circuit board of a disposable camera was separated from the rest of the case. The board contains 1) the capacitor, 2) the flash, 3) the charge indicator, 4) the switch mechanism 5) the contact point for the battery 6) and the charge button. The end of the flash contact point was disoldered and separated from its copper contact. A household electrical switch was soldered to the ends switch mechanism. The coil and barrel portion of the gun consists of a plastic pen tube cut open on both ends. This tube is then wrapped with 22 gauge enamel-coated magnet wire about 50 times for about five layers (250 turns). This coil is held in place by electrical tape and then the ends of the solenoid's wire are sanded down to expose the metal. These ends are then soldered to the points that were previously disordered. One point at the end of the flash bulb and one end is soldered to the copper contact. This construction allows for extra energy to set off the flash bulb, reducing the chance of the coil from burning up (Hove). For aesthetic purposes, the components were placed in a box. The projectile was a steel 4.5mm BB coated in copper.




**Physics**

Biot-Savart Law is the fundamental element that explains the connection between electrical current and magnetism. $B^{\rightarrow} = \int \frac{dlxr^{\wedge}}{r^2}$. $B^{\rightarrow}$describes the vector quantity of the magnetic field, dl represents the section of the current, $r^{\wedge}$ is the direction of that current, and r is the distance of that charge of the point of the magnetic field. This equation is essential for calculating the magnetic field inside the solenoid. Since the length of the solenoid is much greater than the radius, the infinite solenoid equation can be used to calculate the magnetic field inside the tube. $B^{\rightarrow} = \mu_0 nI$. $\mu_0$ is the permeability of free space constant n is the number of turns, and I is the electrical current flowing through the wire of the solenoid. This magnetic force creates a magnetic moment which forces the magnetic material to align with the field and then be push and pulled through the coil and out of the tube. The theories around magnet moments describes how the ferromagnetic material moves through the solenoid (Paul). Another set of equations can be used to describe the efficiency of the gun. The potential energy stored by the capacitor is equal to $\frac{1}{2}C(\Delta V^2)$ where C equals the capacitance of the capacitor, and $\Delta V$ describes the change in current through the solenoid as the capacitor is discharged. Due to conservation of energy, in ideal situations, the potential energy should equal the kinetic energy = $\frac{1}{2}mv^2$ where m equals the mass of the projectile, v equals the exit velocity of the projectile (Brand). These two equations can be used to find the theoretical value of velocity of the projectile in an ideal situation, $v = \sqrt{\frac{C(\Delta V)^2}{m}}$m/s.




**Experiment**

The following experiment was conducted to evaluate the efficiency of the coil gun. Using the equation $v = \sqrt{\frac{C(\Delta V)^2}{m}}$. Theoretically, if all potential energy is transferred to kinetic energy, $v = \sqrt{\frac{120\mu F(330V)^2}{.342g}}$, with the average mass of a single BB coming out to be about .342g the theoretical velocity came out to be 6.18m/s. The will measure time it takes for a BB to travel a given distance. Using the equation v= x/t, the average of six shots will be taken. The theoretical value for the potential energy will compared to the actual kinetic energy.  The ball travels 1.58m.

| Trials | Time (s) | Velocity (m/s) | Velocity$^2$ (m/s)$^2$ | Kinetic Energy (J) |
|---|---|---|---|---|
| 1 | .43 | 3.67 | 13.49 | 2.31 |
| 2 | .45 | 3.51 | 12.33 | 2.11 |
| 3 | .41 | 3.85 | 14.84 | 2.54 |
| 4 | .42 | 3.76 | 14.14 | 2.42 |
| 5 | .40 | 3.95 | 15.60 | 2.67 |
| 6 | .45 | 3.51 | 12.32 | 2.11 |

The average computed kinetic energy is calculated to be 2.36J. To compared to the theoretical potential energy to the calculated kinetic energy, the equation will use the equation efficiency= $\frac{Kinetic\ Energy}{Potential\ Energy}$.

**Calculations**

The capacitor is rated at 330volts and 120 microfarads. Potential energy is calculated U=$\frac{1}{2}C(\Delta V^2)$. $\frac{1}{2}120\mu F(330V^2)$= 6.534J. The magnetic field of the solenoid= $\mu_0\, nI =$ $4\pi x 10^{-7}$ $\text{NA}^{-2} x\ 250 turns\ x\ 330V =$ .104T. The efficiency =$\frac{2.36J}{6.534J}$ 100%= 35% efficiency.

**Conclusion**

The coil gun I constructed produces a very small magnetic field which corresponds to a lower velocity of the projectile. The optimal operation of the coil gun would be if all the electrical energy was transferred into magnetic force. This does not happen because some of the energy is lost through the flashing of the bulb. This prevents the coil from being burnt up, but it greatly reduces the amount of energy through the coil. The position of the BB in the tube is also very important. Placing the BB towards the middle seems to provide the greatest amount of force.  This project could be better if construction involved wire that was less susceptible to burning due to high voltage. More capacitors in series could also provide a greater amount potential energy resulting in a greater magnetic force.

# References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