Hand-Held Coilgun

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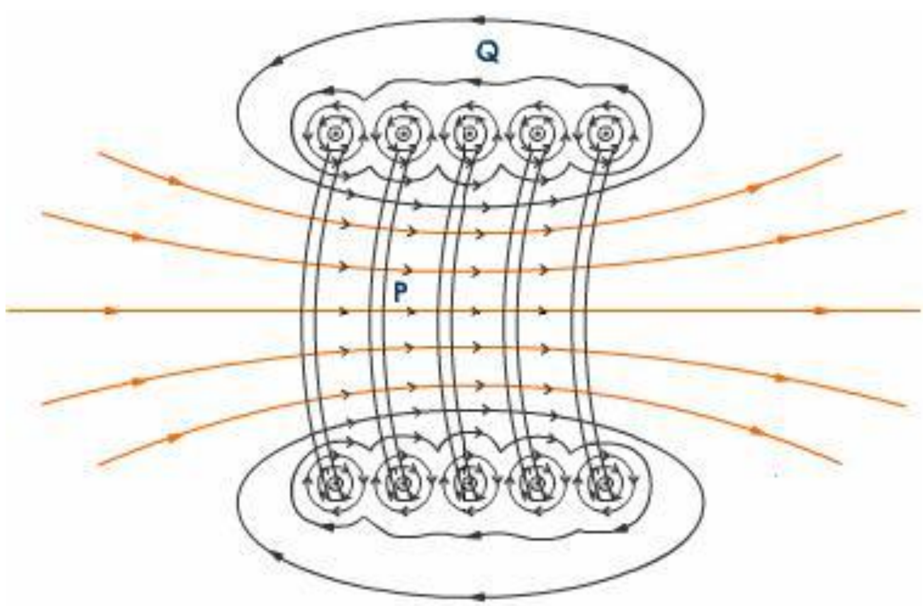
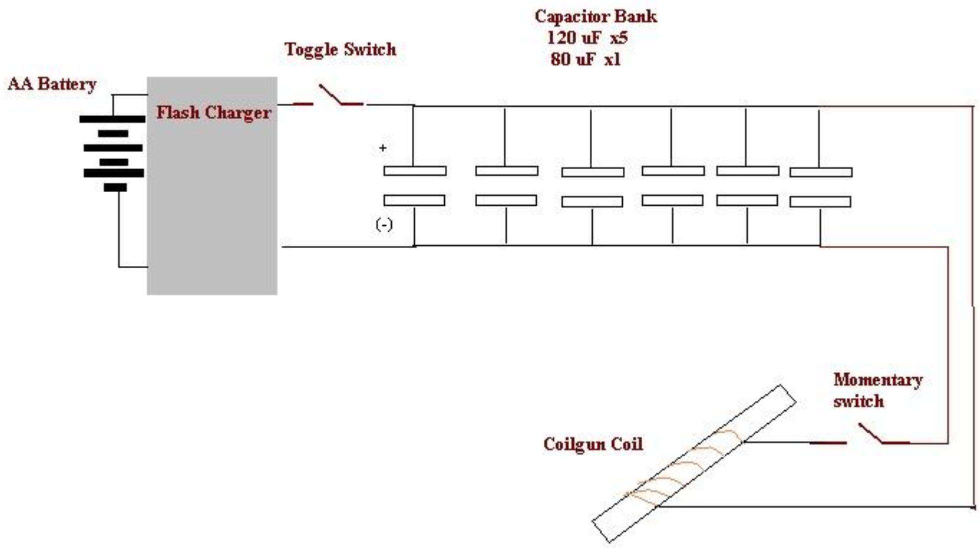
Coilguns are based on the relatively simple concepts that an electric current creates a magnetic field, and that a magnetic field can exert a magnetic force (Lorentz Force). In this case the electric current flows through the coil of a cylindrical solenoid. Due to the Right-Hand Rule, this current creates a linear magnetic field inside the solenoid. So we can connect a solenoid to a battery and the field will push projectiles through it right? Wrong. In addition to the fact that magnetic field and force are completely different things, one must also take into account the timing and strength of the current discharge, as well as the projectile composition.



Magnetic force acts perpendicular to magnetic field, not parallel, but the force still propels the projectile to the right of the diagram. To explain this, one must make a few assumptions. First of all, it is assumed we are using a ferromagnetic projectile. Since there is a magnetic field, the right half of the projectile will take a positive charge and the left negative. Ideally the current would be cut off when the projectile is in the center of the coil, so one should only consider the left half of the diagram. If the current is not shut off, the projectile will oscillate about its equilibrium position in the middle of the coil. Since the positive right half of the projectile will always be in a stronger field, the net force will be based on a positive charge. Using the diagram and the Right-Hand Rule $\mathbf{F = qE + qv \times B}$, to draw force vectors perpendicular to the field in the left of the solenoid will show a net force to the right, this is the force that drives the projectile. (Cowan, *Basic Electromagnetism*)

In order for the coilgun to work, a large and quick burst of current is required. This is where the circuitry and wiring comes into play. This was by far the most painstaking and painful part of the project. Sprays of molten solder to the face and tazer-like shocks are rights of passage that help spice up the hours of tedious tinkering. Capacitors' ability to store and quickly discharge large amounts of energy makes them ideal for powering coilguns. To produce large amounts of current, the higher the capacitance and voltage the better, since $\mathbf{E = (1/2)\ C\ (V)^2}$. The flash circuit boards of disposable cameras happen to provide both high voltage capacitors, and an easy means to charge them. The capacitors have a high voltage rating of 330 V, but a low capacitance of only 120 microfarads. However, multiple capacitors can be connected in parallel to increase total capacitance. The circuit board itself is needed to bump the low voltage of the battery up to 300 V. (Course Guide)



In the circuit diagram above, the toggle switch activated to charge the capacitors, which takes about a minute. Several sources suggested using a light bulb as a resistor to speed charging but that yielded little success.(Parehk) Once the capacitors are charge, the toggle switch is turned off to protect the flash circuit from the jolt of current from firing. The momentary switch is then essentially a trigger for the coilgun.

Calculations:

Potential Energy: **E = (1/2) C (V)^2**

E = 5(.5)(120E-6)(300)^2 + 1(.5)(80E-6)(300)^2 = 30.6 J

Theoretical Velocity: **E = U = KE = (1/2)mv^2**

v = 2 sqrt(E/m) **m ≈ 1.5 gram**

v = 2 sqrt(30.6 / .0015)

v = 285.7 m/s

Actual Velocity: **s_y = h + (1/2)g t^2**

0 = 1m + (1/2) -9.81m/s t^2

t = .45 s

$s_x = v_o t$

4.2m = v_o (.45s)

v_o = 9.3m/s

Actual Kinetic Energy; **KE = (1/2) m v^2**

KE = (1/2) (.0015g) (9.33m/s)^2

KE = .0653 Joules

((30.6 - .0653) / 30.6) x 100

.213% of the Electrical energy is converted to Kinetic

The actual velocity is significantly less than the theoretical because of the resistance of the wire and most of the electrical energy is converted into heat. Regardless, the result is a high speed, very light projectile that lacks the momentum to penetrate anything but can easily shoot across a room. Building a camera flash coilgun is an excellent intermediate project to become familiar with magnetism, electricity, circuits, soldering and wiring.

References:

Cowan, Eugene W. *Basic Electromagnetism*. New York: Academic Press, 1968.

Parehk, Alan. "MV Coilmaster Mark1 Coilgun." *Hacked Gadgets* N.p., n.d. Web. 30 Nov. 2009. <http://hackedgadgets.com/2009/05/07/mv-coilmaster-mark1-coil-gun/>.

World's Coilgun Arsenal N.p., n.d. Web. 30 Nov. 2009. <http://www.coilgun.ru/>.

Dr John and Gay Stewart *UPII Fall 2009 Course Guide*