Physics II Honors Project: Disposable Camera Coil Gun

Joshua Leabres (H1)

Nearly everyone is able to appreciate the powerful feeling that possesses one while firing a handgun. But what can be said about the feeling one gets from actually building a gun. This may sound crazy but the materials needed for building said gun are cheap and easy to obtain. Of course, this weapon of miniscule destruction can only be the COIL GUN.

A coil gun is any weapon that which uses a coil of wire to fire a projectile. It usually works like this. Wire is wound around a tube in several layers, thus creating a solenoid. Charge moving in the wire, a.k.a. current, creates a magnetic field inside the tube. To turn the solenoid into a space-age firearm know as the coil gun, just put a ferromagnetic material close enough to the coil, then allow a brief pulse of current through the coil. The field in the tube induces a magnetic moment in the ferrous material. The induced moment is aligned with the magnetic field, so the material feels a force moving it towards area of stronger field within the coil. The tricky part, however, is timing. If the current were left flowing then the projectile would oscillate in and out of the coil much like a spring because it would always feel a force towards the area of strongest field. This is why a single pulse of current is necessary. To give a projectile maximum velocity, the current must somehow be switched off just before the magnet reaches the region where the strongest magnetic field exists.

The purpose of the project is to build a coil gun and calculate its efficiency. A coil was wound with 15 layers of 30-40 turns each (approximately 500 turns). The flash circuit of a disposable camera was used to trigger the current in the coil. Current is supplied for a very brief time to allow the bulb to blink. Adding the coil in series with the bulb will provide it with the same current that the bulb receives for the same brief instant.

The efficiency of the gun is the ratio of final kinetic energy to initial potential energy.

$$efficiency = \frac{\frac{1}{2}mv^2}{\frac{1}{2}C(\Delta V)^2}$$

The kinetic energy is that of the projectile and the potential energy is that stored in the capacitor. Only one capacitor was used with capacitance equal to 80μF and voltage equal to 330V. Thus the total potential energy of the system is about four and a half joules.

$$U = \tfrac{1}{2}C(\Delta V)^2 = \tfrac{1}{2}(80\times 10^{-6}F)(330V)^2 = 4.356J$$

The kinetic energy of the projectile takes a bit more effort to calculate. The mass of the projectile (BBs were used) can be easily measured. To measure the velocity of the BB, the gun was placed at a height *h* above a level surface. Since the BB is shot out horizontally, the following simplified kinematics equation could be used to find the time *t* it took for the BB to fall the distance *h*:

$$h = \tfrac{1}{2}(9.81 \, {}^{m}\!/_{s^2})t^2$$

The gun was fired and the horizontal distance the BBs traveled before hitting the ground was measured. Assuming that the horizontal velocity of an object doesn't change very much while falling through the air, the average velocity and the muzzle velocity should be close enough to be considered equal. Therefore the equation for average velocity was used to find the muzzle velocity of the BB.

$$v_{avg} = \frac{\Delta x}{\Delta t}$$

Since velocity and mass are known, the kinetic energy of the projectile and the efficiency of the coil gun can be calculated. Because the muzzle velocity is largely dependent on exactly where the BB is placed behind the coil, data from several shots was collected and averaged to give a mean efficiency.

The data collected from the project is as follows:

Mass (g)	Distance (m)	Muzzle velocity (m/s)	Kinetic energy (J)	Efficiency
1.692	0.95	3.32	0.0093	0.21%
1.692	0.88	3.08	0.0080	0.18%
1.015	1.44	5.04	0.0129	0.30%
1.692	1.58	5.52	0.0257	0.59%
2.030	1.29	4.50	0.0205	0.47%

This data was obtained while firing the projectile horizontally from an initial height h = 0.40 *m*. Using the kinematics equation presented earlier, the time it took each shot to fall was t = 0.29 *s*. The mass of a single BB was m = 0.338 *g*. The coil gun built in this project functioned more like a shotgun, shooting several BBs at once. A variable amount of BBs fired out of the gun at different times, so the mass used to calculate the kinetic energy was not always the same for each shot. The average efficiency of five shots is 0.351% (very, very low). Ironically the “gun” could cause a lot more pain if one’s skin shorted the capacitor.

A very large source of error in this project was trying to fire the gun perfectly horizontally because the ammo might roll out. BBs were not such a great choice as they can have a severe effect on the measurement of muzzle velocity. This leads one to guess that the actual efficiency of the gun is higher, about 1%. A smaller source of error could be the heating of the coil after the gun was shot several times.

The coil gun constructed in this project had an average efficiency of 0.351%. This is a terribly inefficient machine. To improve the efficiency, one would work at increasing the magnetic moment induced in the projectile. This can be achieved by winding more turns in the coil. Another possibility is using a strong neodymium permanent magnet for ammo. Yet another way to up the muzzle velocity would be to increase the flow of current in the coil to generate a stronger magnetic field. Overall the project was fun and educational. What more could one ask for?

Sources

Coil Gun. 21 Apr. 2008. 26 Sep. 2008 <http://wiki.4hv.org/index.php/Coil_gun>.

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

Dayley, Matt, and Keith Holbert. Electromagnetism. 21 June 2002. Arizona State U. 27 Sep. 2008 <http://www.eas.asu.edu/~holbert/wise/electromagnetism.htm>.