Electromagnetic Shoot

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Abstract. The science fair device described in this paper shoots a miniature soccer ball using a solenoid and a two-piece rod made of iron and nylon. The nylon part of the rod is introduced inside the solenoid and a ball is placed at its extremity. When an electrical current passes through the solenoid, the iron part of the rod is pushed into its center, causing the shooting of the ball. This mechanism, originally developed for Minho Team soccer robots, has been successfully used for several years. The science fair version includes a slewing iron case and overheat protections.

Keywords. Soccer Robots, Electromagnetism.

1. Introduction

The *Electromagnetic Shoot*, described in this paper, is a device built for science fair events. It was used for the first time in *Robótica 2006* festival (Fig. 1).

Figure 1. *Electromagnetic Shoot* at *Robótica 2006 festival*

The device was a success, in part because it is related with football, which attracts specially the younger ones. A ball is placed in a ball holder. When a button is pressed, the device shoots the ball at a distance of several meters.

The shooting mechanism, shown in Fig. 2, was originally developed by João Sena Esteves for *Minho Team* soccer robots and it has been successfully used for several years.

2. Materials used

The *Electromagnetic Shoot* uses the following materials:

- Diode bridge;
- Capacitor;
- Button;
- Coil (solenoid);
- Two-piece rod made of iron and nylon (Fig. 3);
- Contactor with timer.

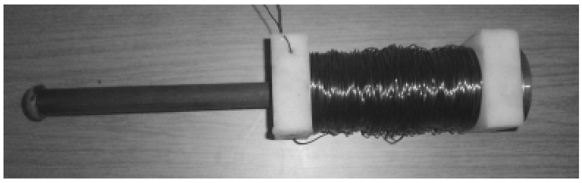

Figure 2. Shooting mechanism

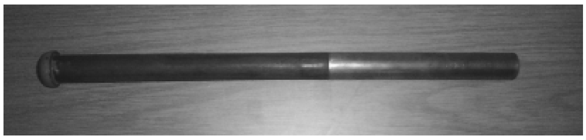

Figure 3. Two-piece rod made of iron and nylon

3. Device operation

This device operation is based on Electromagnetism laws. When a button is pressed, a current passes through a coil, creating a magnetic field whose direction is given by the right hand rule (Fig. 4). The field attracts the iron part of a two-piece rod made of iron and nylon, whose displacement causes the shooting of the ball (Fig. 5).

The circuit used to produce a current on the coil is shown on Fig. 6. The 220V/50Hz mains voltage (Fig. 7) is rectified (Fig. 8) in order to produce a stronger current and, therefore, a stronger shooting force.

A diode bridge is used to rectify the mains voltage. At its output, the voltage is not constant, yet. To accomplish this, a capacitor is added to the circuit.

The described circuit is switched on when a button (not shown in Fig. 6) is pressed.

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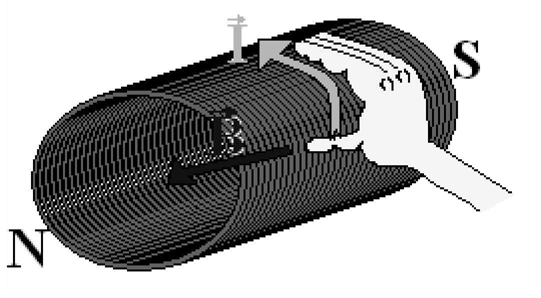
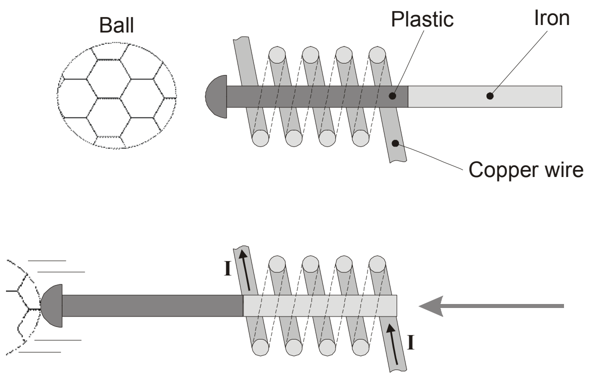


A coil (solenoid) is made of a large number of series-connected wire loops. When a current flows in a coil, it generates a magnetic field whose direction is given by the right hand rule. With your right hand, extend the thumb and curl the other fingers around the coil, in the direction of the current. The thumb points to the north of the magnetic field [1,2].

Figure 4. Solenoid



Iron has orbital electrons that are organized in small groups called *domains*. The domains are randomly positioned. When an electrical current flows in the coil it produces a field, which will order the magnetic dipoles of the iron. This alignment of the orbital electrons will push the iron part of the rod into the center of the coil, making the nylon part shoot the ball.

Figure 5. Shooting mechanism operation

A temporized contactor (not shown in Fig. 6) was added to the circuit. This contactor prevents overheating of the coil, since it switches power off automatically – after a predetermined time – even if the power button is kept pressed.

The shooting mechanism was fastened inside an iron case mounted on a turning base (Fig. 9), which was developed to allow shooting the ball in any direction within a 90º angle.

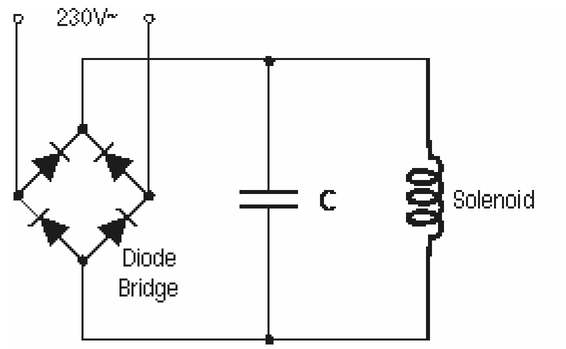


Figure 6. Electric circuit

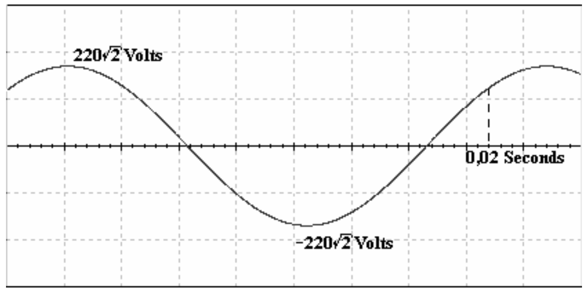


Figure 7. Mains voltage waveform

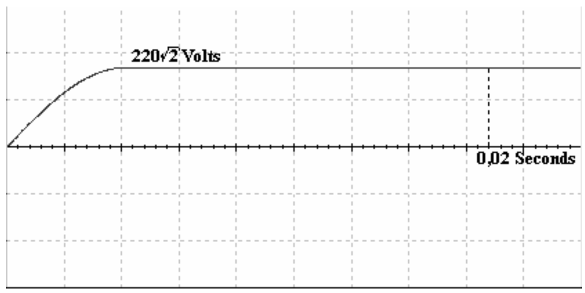


Figure 8. Rectified wave applied to the coil

4. Conclusions

An electromagnetic shooting mechanism, originally developed for soccer robots and capable of shooting a miniature soccer ball at a distance of several meters, has been presented in a science fair version. The device includes a slewing iron case and overheat protections.

The *Electromagnetic Shoot* is a fun experiment because it's related with sports, more precisely with soccer. But it also is educational, since it illustrates Electromagnetism laws. Its operation principle is the same used in other electromagnetic devices like relays and contactors.

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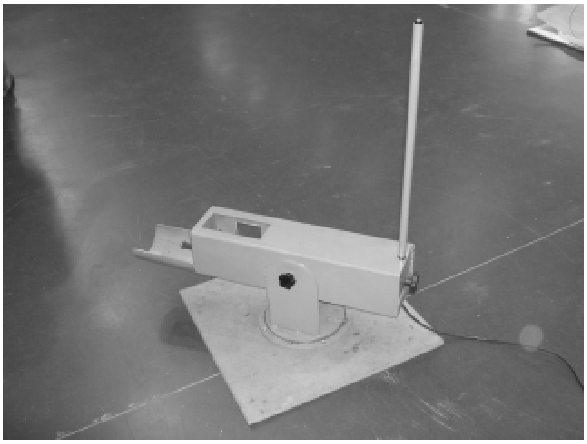

Figure 9. The *Electromagnetic Shoot* has an iron case mounted on a turning base

The device has been a success as a science fair attraction. Building it was exciting. It was an opportunity to learn a lot and gain experience, too.

5. References

[1] Plonus, Martin A.; Applied Electromagnetics. McGraw-Hill, 1986.
[2] Mendiratta, Sushil Kumar. Introdução ao Electromagnetismo. Fundação Calouste Gulbenkian, 1984.

Induction Coil Gun

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Abstract. This paper describes a device capable of throwing metal rings at a range of a few meters. Part of an iron pipe is inserted on a coil. A conducting non-ferromagnetic ring is inserted in the pipe through its other extremity. An alternating current flowing through the coil creates an alternating magnetic field, which magnetizes the iron pipe. So, an alternating magnetic field is created around the pipe and induces a circumferential current flowing in the ring. This current is repelled by the magnetic field, forcing the ring to jump out of the pipe.

Keywords. Coil Gun, Jumping Ring, Thompson's Coil.

1. Introduction

The apparatus described in this paper was invented by the American engineer and inventor Elihu Thompson (1853–1937) [1] to demonstrate his pioneering research in alternating current and high frequency.

The recreated device is capable of throwing metal rings using Electromagnetism laws formulated by Biot-Savart, Ampère and Faraday-Lenz [2,3]. Further explanations will be merely qualitative. Thompson's jumping ring is a great experiment to demonstrate Electromagnetism laws in science fairs and hands-on classes.

The device is composed by a coil, winded around an extremity of a ferromagnetic core, leaving about two thirds protruding (Fig. 1). The projectiles are conducting non-ferromagnetic rings. The coil is driven by an alternating current for a short period of time, until the ring leaves the core.

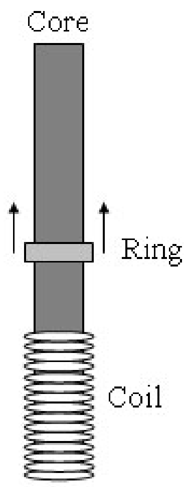

Figure 1. Schematic of the apparatus

The recreated device (Fig. 2) was made with an iron pipe with 600mm length and 60mm diameter, as core. Around 200mm of the length of the core, about 800 turns of 0.90mm insulated copper were winded. Rings were made to fit around the core and are made of aluminum, copper and brass.

For safety reasons, core and coil were fit in a structure that prevents aiming upward, in a direction perpendicular to the ground. A fixed angle of 30º with horizontal direction was imposed, making rings jump forward.