

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.
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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.

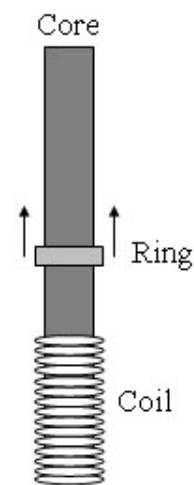


Figure 1. Schematic of the apparatus

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 30° with horizontal direction was imposed, making rings jump forward.

The structure can rotate, so the operator can choose the horizontal direction. This way, the device can easily be used as a 'shoot the target' science fair game, with variable direction and multiple projectiles with different shooting ranges.

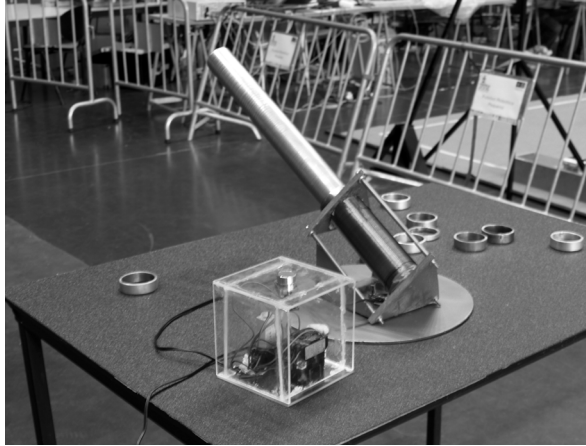


Figure 2. The apparatus

2. How it works

The coil gun works on the principles of electromagnetic induction and repulsion [4]. When it is fired, an alternating current flows through the coil creating an alternating magnetic field. The field magnetizes the iron, which induces a circumferential alternating current in the ring. This current is repelled by the magnetic field, making the ring jump from the core at a distance of a few meters.

The faster the magnetic flux changes, the greater are the induced currents in the ring, resulting in a stronger force.

3. Step 1 – Creating a magnetic field

As described in the previous chapter, the device is driven by an alternating current, which flows through the coil creating a magnetic field around it (Biot-Savart's Law).

When the current flows in a circular direction, the resulting magnetic field is similar to a magnet, with the field flowing from the North pole to the South pole.

The created field is not strong enough to magnetize the core unless strong currents are used. In order to reduce the employed currents maintaining the field value, it is required to add more turns to the coil. This way, the field created by each turn will add up, resulting in a stronger magnetic field.

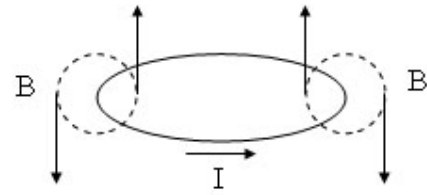


Figure 3. Magnetic field in a circumferential current

Fig. 4 and Fig. 5 represent the magnetic field lines created by a coil with an air core. Using a core protruding from the coil will change this magnetic distribution, resulting in a slightly different magnetic field (Fig. 6).

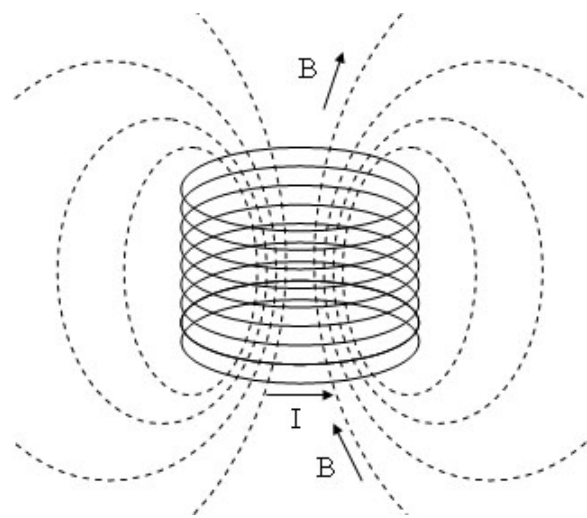


Figure 4. Magnetic field generated by several turns

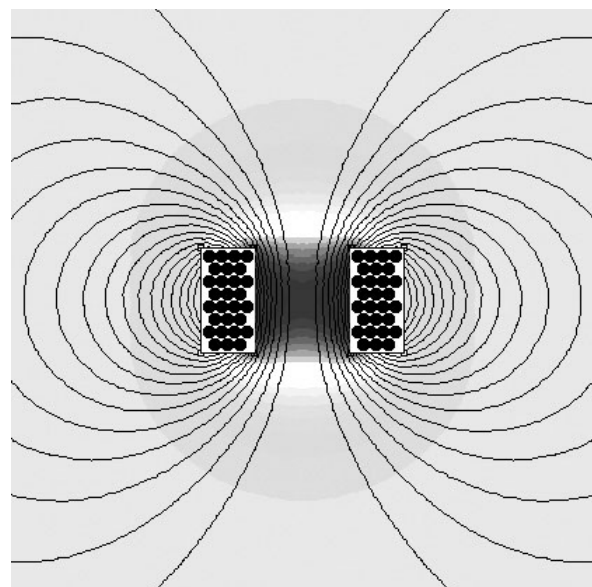


Figure 5. Magnetic field generated by a coil (simulation)

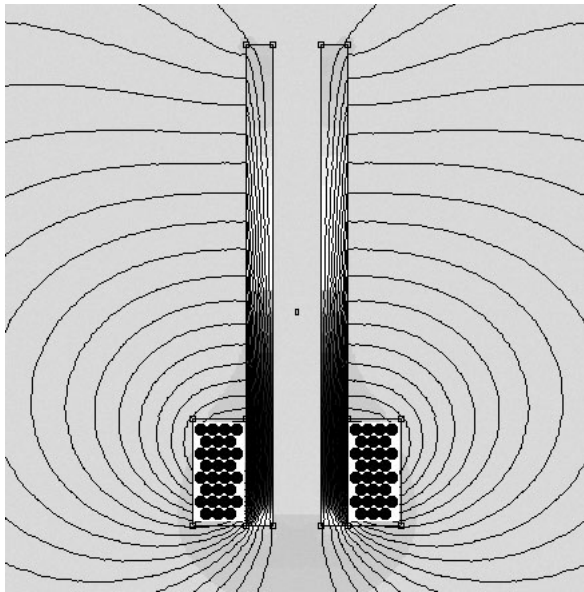


Figure 6. Magnetic field generated by a coil with core (simulation)

4. Step 2 – Inducing a current in the projectile

Because the current in the coil is alternating, so will be the magnetic field in the coil and the magnetic flux in the core (Fig. 7). This alternating flux induces a voltage in the ring (Faraday-Lenz's law). Since the ring is a closed circuit with low resistance, the induced voltage creates a circumferential current in it. The faster the magnetic flux changes, the greater is the induced current.

From this point, every time the induced current is referred, it should be understood as the current resulting from the induced voltage.

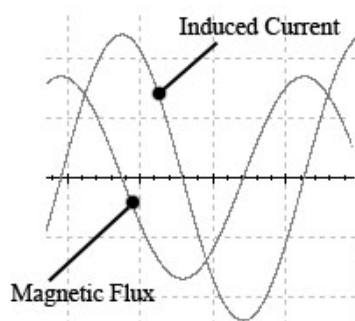


Figure 7. Induced Current and Magnetic Field

5. Step 3 – Magnetic repulsion

A current flowing in a magnetic field suffers an action of a force (an equation to determine this force was a result from the experimental work of Ampère and Biot-Savart [2]). Two conductors with currents flowing in the same direction are attracted to each other and two conductors with currents flowing in opposite direction are repelled from each other (Fig. 8).

The same applies to two parallel conductors with the shape of a ring. Using currents that flow in the same direction makes them attract each other. Using currents that flow in the opposite directions makes them repel each other (Fig. 9). This is the repulsion principle of the apparatus. The current in the coil is opposite to the induced current in the projectile, resulting in a force applied to it (Fig. 10).

But is the current from the coil really opposite to the induced current? The alternating current applied to the coil creates in the core an alternating magnetic flux that is directly proportional to the current and induces an alternating current advanced $\pi/4$ from the source current [5]. So, the resulting force is repulsive in half a period and attractive in the other half. If repulsive and attractive forces were of the same magnitude, the projectile would remain motionless, or oscillate around a point, due to the balanced resulting effect. A more careful analysis shows that this does not take place. The ring is actually launched, so the resulting effect cannot be a balanced one. In fact, the repulsive forces are stronger than the attractive ones, creating an overall repulsive force.

6. Other experiments

Many other experiments could be performed with this apparatus. For instance, making someone hold the projectile and applying an alternating current to the coil. The person holding the projectile will immediately drop it, as it heats up due to the induced currents. This experiment illustrates the principle of operation of induction ovens.

Directing the gun upward, applying an alternating current to the coil and only then inserting a projectile on it will make the ring levitate. This results from a balance between the force of the magnetic field and gravity force.

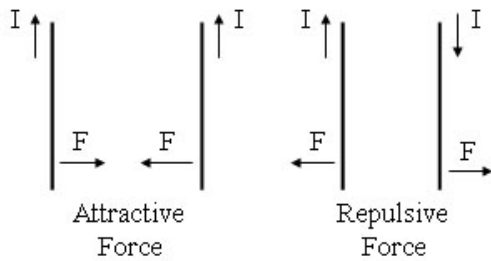


Figure 8. Forces between two parallel conductors

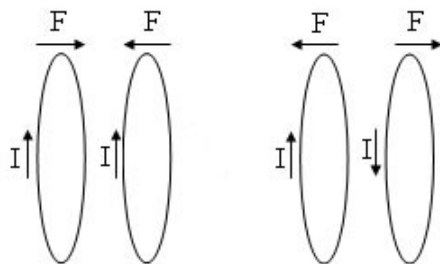


Figure 9. Resulting forces between two rings of the coil

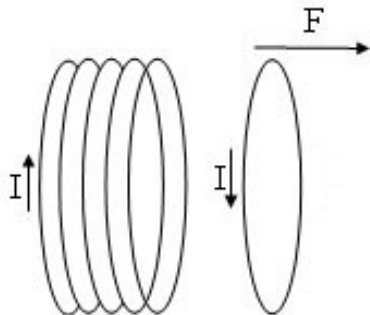


Figure 10. Resulting force in a ring

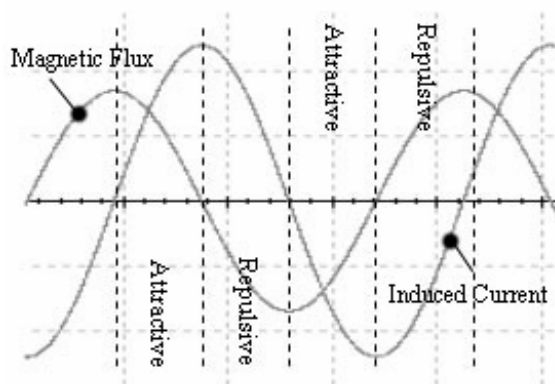


Figure 11. Resulting forces in a period of time

7. Conclusions

A device capable of throwing metal rings at a range of a few meters has been presented. The physical principles that rule its operation were briefly introduced. Also, some construction details have been given. The experiment is very appropriate to demonstrate Electromagnetism laws in science fairs and hands-on classes.

8. References

[1] Famous Electrochemists
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 [2] Plonus, Martin A.; Applied Electromagnetics. McGraw-Hill, 1986.
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Miniature Thermoelectric Power Plant

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Abstract This paper describes a miniature thermoelectric power plant made with the boiler and the water pump from an old starch iron. It also uses a computer cooling fan, which serves as electric power generator. The boiler vaporizes the water it receives from the water pump. Then, the steam is injected over the turbine of the fan making it twirl. The voltage generated by the fan is enough to lighten a couple of LEDs. A wooden case with a chimney encloses all the referred devices.

Keywords. Electrical Power Systems, Thermoelectric Power Plant.