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Demonstration Of The Lorenz Force Using A Spark Gas Discharge

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***Abstract* – The article discusses a device for demonstrating the Lorenz force in the process of studying physics. The device uses a spark gas discharge between two sharp electrodes at normal atmospheric pressure. Details are technical data of parts of the device for possible repetition of the design.**

Keywords—physics course; demonstration of experiments; Lorenz force

I. INTRODUCTION

If a particle carrying a charge q moves in an electric and magnetic field with a speed **v** , then the force **F** acting on it is equal to:

$$\mathbf{F} = q (\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

Where **E** - electric field and **B** - magnetic induction.

This force is called the Lorenz force [1].

However, quite often, the Lorenz force implies only the magnetic component $\mathbf{F}_m$:

$$\mathbf{F}_m = q\mathbf{v} \times \mathbf{B} \quad (1)$$

In our article, the Lorenz force, we will also understand the force $\mathbf{F}_m$.

To our knowledge, for the first time, a spark gas discharge at normal atmospheric pressure was used to demonstrate the Lorenz force in work [2]. Subsequently, the demonstration experiment was improved in work [3]. In this work, a spark discharge occured between a point central electrode and a circular external electrode.

The generator provided high- voltage pulses with a maximum voltage of approximately 30 kV. The pulses were roughly triangular with a fast rise and slow voltage drop. The total pulse duration, which almost all fell on its falling front, was 17 µs. The pulse period was 70 µs, that is, their frequency was 14,3 kHz. The average spark current was 2.9 mA.

Under these conditions, the spark discharge was a clearly visible thin and continiuous violet «thread». The spark discharge was directed from the center electrode to the circular one, that is, along the radius of the circular electrode. Under the discharge it was possible to place a permanent magnet so that the lines of magnetic force were perpendicular to the discharge filament. The distance between the discharge and the surface of the magnet can be changed manually. When the magnet approached the discharge, the «thread» began to rotate, this representing a kind of «plasma motor». When changing the direction of the magnetic field, the direction of rotation also changed. With a decrease in the distance between the magnet and the spark discharge, the rotation speed increased.

The rotation of the discharge is explained by the fact, in accordance with formula (1), the Lorenz force always acts perpendicularly to the velocity of the charges, that is, perpendicularly to the radius of the outer circular electrode.

For all spectacularity of this process, it is perhaps more obvious to demonstrate the Lorenz force is the effect of a magnetic field on the spark discharge occurring between two sharp electrodes. Based on this consideration, the following device was built.

II. DEVICE DESIGN

The two electrodes in this device are two sharp pieces of stainless steel wire. Their diameter was 1.2 mm. Electrodes are placed on cylindrical aluminium supports. The distance between the tips of the electrodes can be changed. In our case, it was 6 mm.

All high-voltage parts of the device are protected by plexiglass plated for safety. This protection is also provided for supports of wire electrodes. The small box that surrounds the supports has a transparent plexiglass lid so that you can observe the behavior of the spark discharge with the help of a document-projector. On the side, this box has a slot for introducing a permanent magnet under the spark discharge and for manipulating it. In addition to security measures, a closed box also protects the spark discharge from accidental air currents. A spark discharge in the absence of a magnetic field has the form of a straight luminous filament. The appearance of the device is shown in Figure 1.

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Fig.1. Appearance of the device for the demonstration of Lorenz force.

The source of high-voltage with some exceptions is similar to the source described earlier in previous work [3]. In particular, the voltage regulator was excluded, which significantly simplified the circuit. A high-voltage generator has also undergone some changes (see Fig.2). As transistor VT1 used Darlington-transistor. In particular, this made it possible to significantly increase the resistance of the resistor R3 in the base of the transistor and reduce its power. In addition, it somewhat reduced the total current consumed by the device. The transistor is located on an aluminium radiator with an area of approximately 120 sq.cm. It does not require additional forced cooling.

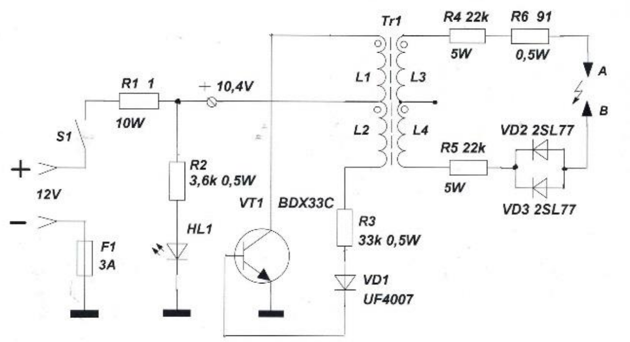

Fig.2. Electrical circuit of the device for the demonstration of Lorenz force.

The powers of all the applied resistors, which are indicated in the circuit, are selected with considerable reserve. They can be reduced at least twice.

As a high-voltage rectifier diodes in this device used diodes 2SL77. In contrast to the circuit given in work [3], they are connected in parallel.

The transformer Tr1 is made on a square-shaped ferrite core with a side of 6.6 cm and a section of the magnetic core of about 2 sq.cm. The magnetic material is manganese-zinc ferrite with a magnetic permeability of 2500. Winding L1 of the transformer is made of a wire with diameter of 0.85 mm, and contains 9 turns. Winding feedback L2 contains 8 turns and is made of a wire with diameter of 0.4 mm. High-voltage windings L3 and L4 are interconnected in series and are placed on opposite sides of magnetic core. Each of the windings is wound on the acrylic four-section frame. Each section contains 150 turns of wire with a diameter of 0.18 mm and is impregnated with paraffin. All high-voltage terminals are covered with silicon. The windings L1 and L2 are wound on the side of the core between the sides on which the coils L3 and L4 are placed. The beginnings of each winding are marked with circles on the circuit.

The device is powered from a DC adapter with a voltage of 12 V and maximum current of 3 A. The power on indicator HL1 is a flashing red LED. If desired, this LED can be replaced with almost any LED. When the device is switched on, the total current consumption is 1,6 A.

Resistor R6 is a measuring resistor. Voltage from it can be applied to the oscilloscope to observe voltage pulses. If these actions are not foreseen, this resistor can be excluded from the circuit.

The duration of each voltage pulse is 30 µs. Almost all this time falls on the falling edge of the pulse. The pulse repetition period is 90 µs, i.e. their frequency is 11.1 kHz. The average current in the spark discharge is approximately 4 mA.

To create a magnetic field, a neodymium magnet with magnetic induction near the surface of 0.14 T was used. If there is a small distance between the spark discharge and the magnet, the discharge can «overleap» to the metal surface of the magnet. To prevent this from happening, the surface of the magnet is coated on both sides with a dielectric layer. The magnet itself is mounted on an insulating plexiglass handle.

III. DEMONSTRATION OF THE LORENZ FORCE

When the device is turned on between the sharp electrodes, a clearly visible «thread» of the spark discharge appears. In an enlarged view, this can be seen in Fig.3. When inserted through the slot of the protective box under the spark discharge of a magnet, this « thread » is bent (see Fig.4). The degree of curvature increases with decreasing distance between the magnet and the spark discharge. The discharge is bent under the action of the Lorenz force in accordance with formula (1). Knowing the polarity of the electrodes and the direction of the magnetic field, it is easy to determine the direction of the Lorenz force. If we change the pole of the magnet, then the Lorenz force will act in the opposite direction, in which the curvature of the discharge will be directed.

Fig.3. Shape of the spark discharge in the absence of a magnetic field.

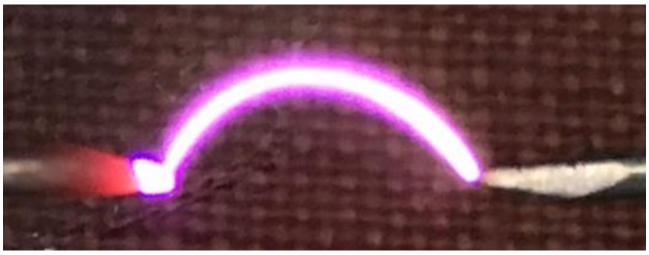

Fig.4. Shape of the spark discharge when a magnet is installed under it.

IV. CONCLUSION

This article describes in detail the device for demonstration of the Lorenz force using spark gas discharge. Discharge occurs between two sharp electrodes at normal atmospheric pressure. The device is simple in construction, making it easy to repeat. The device is designed to demonstrate the experiment in the lecture-room with the help of a document-projector. In this case, the direction of the Lorenz force is well traced on the screen, depending on the directions of the speed of the charges and the magnetic field. In our opinion, a demonstration using this device helps in the process of studying physics to better assimilate the concept of the «Lorenz force».

REFERENCES

[1] Alvin Hudson and Rex Nelson “University physics” Second Edition, Saunders college publishing, USA, 1990, p. 691.

[2] Amit Ram Morarka, Chaitanya Dixit “Low cost demonstration experiment Lorenz force: Change in path of charget particles in magnetic field” Resonance, 2013, Vol.18, Issue 9, pp. 849 – 855.

[3] Aleksei Gavrilov “Demonstration of the Lorenz Force in the Study of Physics” American Journal of Engineering Research” 2019, Vol.8, Issue 1, pp.15-19