

On the Making of a Magnetoscope, As Compared with the Electroscope, For the Use in Magnetostatic Studies

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Abstract

It is important to be able to measure the amount and polarities of the electric charges, the same is true for the magnetic charges, if they existed. Historically, there is the electroscope which has been used very early on for the electrons, but nothing has been done for the magnetic charges so far. To develop a magnetoscope for the purpose of identifying the polarity and number of magnetic charges would be very useful. It is the purpose of this paper to describe such a device in its primitive form. More importantly to show that the magnetic charges (collections of monopoles) do exist and readily measurable with this new magnetoscope. Some advancement of this instrument could make its use as common as electroscope for electric charges. The details of this development will be described.

Keywords: Electroscope, magnetoscope, magnetic monopoles, magnetostatics, electrostatics.

1. INTRODUCTION

One of the basic properties of magnetism is that a magnet always has two poles, north and south, which cannot be separated into isolated poles i.e., MMs (magnetic monopoles). However, there are strong theoretical reasons why they should exist.

Dirac's idea [1] of possible existence of the MMs led to very extensive theoretical and experimental work in recent years. The most experimental searches are the so called 'spin ice' at low temperatures [2]. However, their work is not a direct probe of MMs and rely on the theoretical interpretations of the results.

In the early study of electromagnetism, the use of electroscope is a powerful tool to observe the electric charges in materials. They are easy to make and can be used to demonstrate the principle of electrostatics and the Coulomb's forces between electric charges [3]. Using the thin gold foil, one can make the small repulsive electric forces visible. This electroscope is still used for physics education to demonstrate the basic principles of electromagnetism. However, there is no such counterpart for the magnetic charges.

There are recent experimental results which show that the monopoles do exist [2, 4]. It would be useful to observe the magnetic charges directly and prove its existence in analogues to the electric cases.

It is the purpose of this paper to present the concept and the making of a prototype of magnetoscope. Using the same principle as an electroscope, we make use of two magnetic materials, such as iron or nickel pieces. Just like the electric charges, the Coulomb forces between the magnetic charges make the two magnetized pieces, either open or closed depending on their polarities and number of charges may be displaced. In addition to a Gauss meter, to supplement the measurement, we make use of the iron powder to map out the magnetic field lines distributions between the two testing pieces. It is believed that this is the first time such details of measuring the magnetic charges directly with a magnetoscope appeared in the literature. Further development of this equipment could make it available to all laboratories or schools.

2. EXPERIMENTAL METHODS

In the following, three separate experiments will be described. Two different rods were used to transfer the magnetic charges. And a new method for mapping the magnetic field will be given.

2.1. With a permanent magnet on top, which hangs two pieces of book binder (cut up into half length, made of iron) as shown in Figure 1. Depending on their magnetic polarities, they will either repel (same) or attract (opposite) to each other according to the Coulomb's law of force for the magnetic charges. They form either a 'V' or an inverted 'V' shape (see the magnetic field patterns in Figure 2 and 3 and the descriptions of the section 2.3. below). The distance and angle of separations can be used to estimate the number of magnetic charges. A typical example was given in an earlier paper [4].

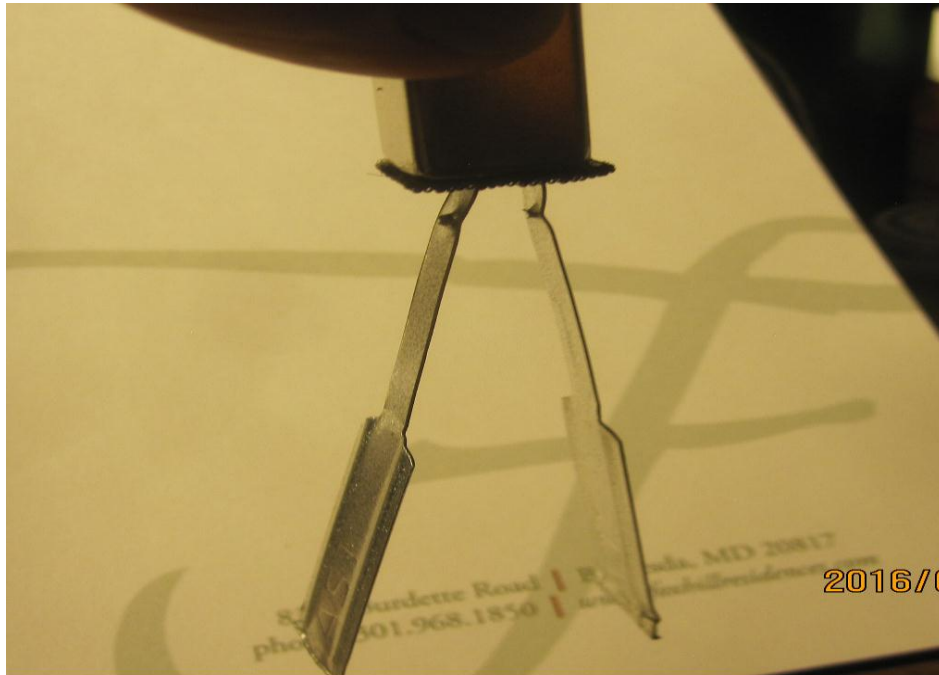


Figure 1 . A permanent magnet is at the top. The two book binders of length L , open to a distance X due to the coulomb repulsive force. ($L=6.5$ cm, weight= 1.48 gm, width= 1.3 cm and thickness= 0.033 cm)



Figure 2 . The magnetic field lines of two arms with the same polarities. They repel each other and give an inverted 'V' shape as shown. (Dimensions of each arm: 8 cm long, weight 2.9 gm, 1.3 cm wide and 0.033 cm thickness)

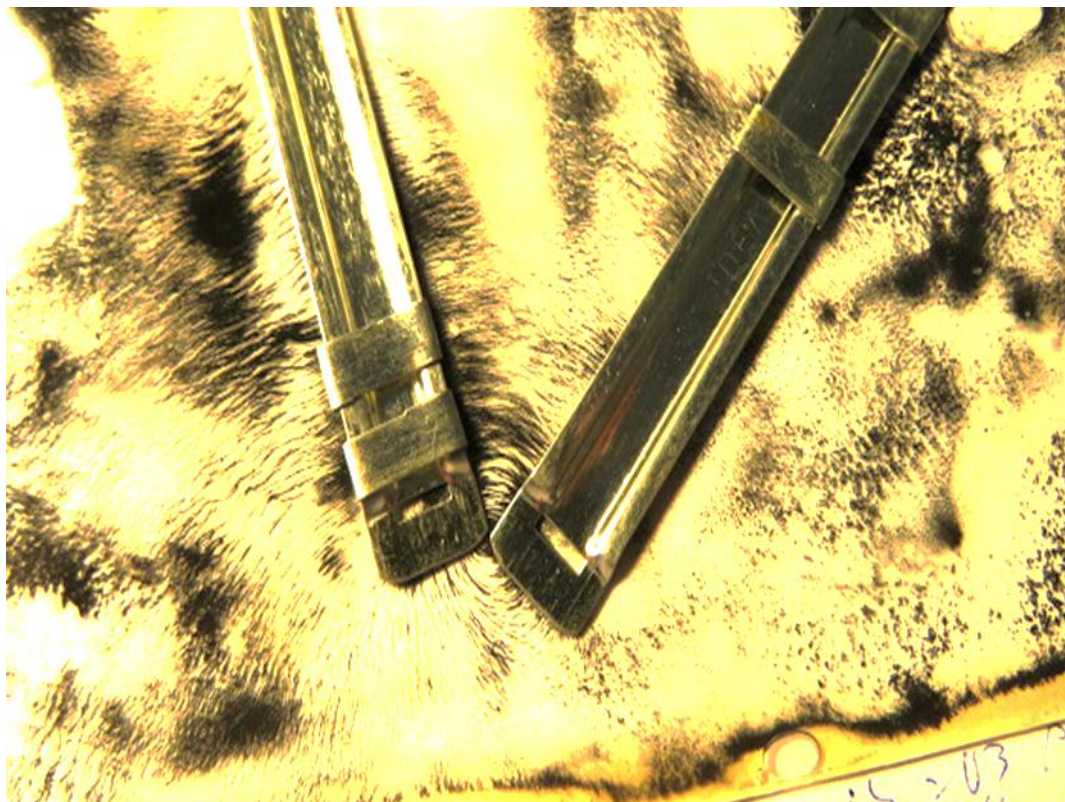


Figure 3. Two arms having the opposite magnetic charges. They attracted to each other and gave a 'V' shape as shown. (Dimensions of each arm: the same as in Figure 2)

2.2. Two small pieces of the Nickle stripe about 3 cm each were attached at the end of an iron bar, as they form an inverted 'V' shape as shown in Figure 4(B), (Suppose that they both have North charges). If one put a magnet of N polarity near the bar, say 2 cm above the end, the induced N charges to the bar will make the opening larger. In addition, if one used a magnet of S polarity near the bar instead, which induced S charges. The affect is to decrease the attraction between the Ni pieces which result their sudden drop and detached from the bar. The magnet can transfer the magnetic charges to the bar by conduction. Therefore, one can use the testing magnet to determine the polarities of the Ni pieces. Just the same way as an electroscope does. On the other hand, if both Ni pieces were of opposite polarities, a 'V' shape is formed due to the attractive forces as shown in Figure 4(A).



Figure 4(A): Two Ni pieces of opposite magnetic charges, form a 'V' shape, due to the attractive forces between them. (Dimensions of the Ni pieces: 3.1 cm long, weight 0.11 gm; All four pieces, including in Figure 4(B) having thickness of 0.01016 cm, and a width of 0.4 cm). (The magnetic field lines are similar to those of Figure 3).



Figure 4(B): Two Ni pieces of the same magnetic charges, form an inverted "V" shape, due to the repulsive forces. (Dimensions of the Ni pieces: 4.0 cm long, weight 0.15 gm.) (The magnetic field lines are similar to those of figure 2).

To estimate the magnetic charges in each sample, we used the same equations given for the similar calculations of electric charges from the textbook by Holliday, Resnick, and Walker [5], P. 518, problems 15P as follows:

For *electric charges*; Coulomb's force between the two point charges of the same polarities:

$$F = (1/4\pi\epsilon_0)(q_e^2/x^2) \text{ which gives: } x = (q_e^2 L/2\pi\epsilon_0 mg)^{1/3}$$

$$\text{Or } q_e = (x^3 (2\pi\epsilon_0) mg/L)^{1/2}$$

Where L and m are the length and the mass of the sample respectively, and x is the distance between the two charges. In this example, the charges are at the ends of both arms.

- Similarly for *two magnetic charges*:

$$F = (\mu_0/4\pi)(q_m^2/x^2) \text{ which in turn gives:}$$

$$q_m = (x^3(2\pi)L\mu_0 mg)^{1/2}$$

Using the data of # 7226; (thickness = 0.01016 cm)

L = 3 cm, x = 2.33cm, which gives; $q_m = 1.566 \text{ A-m}$.

The smallest quantized magnetic charges are $3.2914 \times 10^{-9} \text{ A-m}$, refer to [7].

Therefore, *the number* of the units involved: $n = 1.566 / 3.3 \times 10^{-9} \text{ unit } n \approx 5 \times 10^8 \text{ units}$

NOTE: We assume the magnetic charges are concentrated at the bottom of the bars. (As in the example given in the textbook). In the situation here, it is evenly distributed along the bar sample. Therefore, the calculated results are a bit off by using half of the L value instead.

2.3. A new technique of mapping the magnetic field with fine iron powder:

In complement and confirm the measurements of magnetic charges with a Gauss meter and compass, we try to refine the magnetic powder technique used in the past, for example [6] p.687. We make use a transparent plastic bag, (such as a Ziploc bag). With a few drops of thin oil in the bag, (such as vegetable oil) mixed and spread evenly with small amount of fine iron powder (mesh 325 size, about 44 μm in diameter). The

magnetic field can be mapped out with the magnetized sample lying either on top or under neath the plastic bag. With this improvement, one can have much better resolution due to the fine dispersed powder separated by the fluid. The magnetic field plots were made to show the separations due to Coulomb forces between the pieces of the same (inverted 'V': Figure 2) or opposite (the 'V': Figure 3) magnetic charges. It also shows that each piece has its own magnetic polarities either North or South.

To test the capability of this new mapping technique, a picture of the magnetic field lines around a magnetic monopole cluster (the end view of a large steel file with single polarity, North in this case) is showing in Figure 5. This is like the electric field lines around an electric point charge [6] p. 561. To the best of our knowledge there was no image of a point like magnetic monopoles with single magnetic polarity appeared in the literature so far.

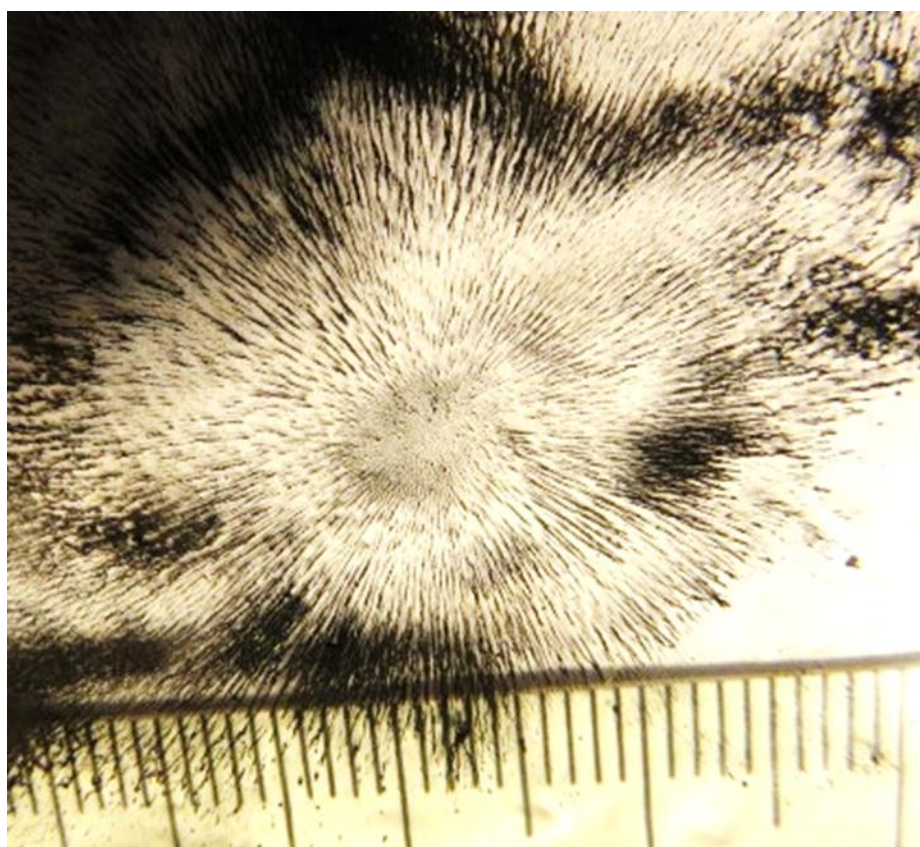


Figure 5. The magnetic field lines of a collection of monopoles (with single North pole). It is from a tip of an iron file rod with magnetic charges of about 2 A-m.
Each scale below is in mms.

3. DISCUSSIONS

The characteristics of the magnetoscope described here have very similar features as the electroscope for the electric charges as illustrated well in the textbook, for example see reference [6]. One of the important functions of the magnetoscope is to provide *visual evidence of the magnetic charges* which do exist and measurable, just like the electric charges.

It is interesting to point out that the 'V' shape (i.e., the display of attractive Coulomb's force between the two pieces) set up *was not* being used in the electroscope. This could be due to the use of the gold foil which is too fragile and not so easy to work with two separate arms. However, it presents no problems for the magnetoscope. This can be observed from the estimated Coulomb's forces between magnetic charges, which are 4700 n^2 times larger than the electric counterpart [7]. With the n value ($=5 \times 10^8$) estimated in section 2.2, which gives an order of magnitude of 10^{20} difference between the two forces with the equivalent charge units. In other words, much larger pieces can be used for the measurements for both 'V' or inverted 'V' types in designing the magnetoscope.

4. CONCLUSIONS

The preliminary studies of basic principles for making a useful magnetoscope were made. It can visually display and detect magnetic charges of either polarities and provide the information to estimate the amount of charges in the sample. It is equivalent to an electroscope for measuring the electric charges. This makes the measurement of single pole magnetic charges (magnetic monopoles) much easier. It is different from the use of a modern magnetometer in that it offers *direct visual evidence* of the interaction between the magnetic monopoles due to Coulomb's law of force. The magnetoscope can be used mostly for demonstrations of magnetostatics in the laboratories and schools, just as the use of electroscope for electrostatic studies. Further improvement of the instrument is possible by using thinner magnetic materials, and a better way to handle the two small pieces of magnetic samples, etc. It is believed that this is a first step toward the development of making use of magnetoscope into a wider application for future use in science and industries, just like the earlier years of developing the electroscope.

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