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On the Measurements of the Effective Mass of Magnetic Monopoles: A Gravitational Effect

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Abstract

It is assumed that magnetic monopoles should have mass associated with the particles. Just like electrons should have mass, and it is an important parameter for any elementary particle. The question is how to measure them in the experiments. We have made some discovery that the gravity may affect the movement of the magnetic monopoles, and their inertia effects may be measurable and estimated. The mass of a monopole so obtained is estimated in the range between 10^{-11} and 10^{-12} Kg. They were comparable with the values of some theoretical estimates. It is believed this is a first direct measurement of the effective mass of a monopole in a magnetic material. The experimental details will be given in this paper. Further experiments along this direction are also suggested.

Keywords: Effective mass, magnetic charges, monopoles, gravity effect

1. INTRODUCTION

The idea of that magnetic monopoles (MMs for short), stable particles carrying magnetic charges, ought to exist have been very intensively searched. The issue was first described by Dirac [1] and developed further later by many others [2]. However, the experimental prove of the existence of MM's is still rather uncertain. The physical properties of an electron are well known, but not for the magnetic charges. However, there are many papers gave the theoretical estimates of the possible mass of a monopole [3]. Most of the theoretical predictions were for the particle physics because they set a lower limit with the present available particle accelerators. In a paper [4], the measurement of AC susceptibility in spin ice was discussed. An earlier measurement of the mass of a domain wall about 7.2×10^{7} m_e was also mentioned [5]. In a review article by Preskill [6], he quoted a number for the mass of monopole, using the grand unified model, to be about 10^{16} Gev which gives the mass app. 10^{-11} kg. He also mentioned other estimates for high energy particle physics (Pages 518-520 of [6]).

Depending on the models used by many others [7], the value for the mass varies within a large range from each other. For example, in a recent article [8], estimated for colliders and in the cosmos, masses of the order of 10^{14} to 10^{16} Gev are also mentioned. However, it is believed that the magnetic particles they discussed are very different from the one found in the magnetic materials as discussed in the present paper and other solid materials [9].

It is the purpose of this paper to describe our findings of the effective mass of a magnetic monopole from the gravity effect and compared with the theoretical values from different models mentioned above. At the same time, provide the experimental fact of the fallings of a large collection of magnetic particles with single polarity due to the gravitational force.

2. THE EXPERIMENTAL DETAILS

With a Gauss meter (Model TD8620 by Tunkia) one can observe the changes in the magnetic field at a particular location on a magnetic material or a permanent magnet by attaching the sensor firmly to the sample. By following the movement of the sample vertically up or down, the changes in the field can be read off from the Gauss meter which is related to the magnetic charges there. One can also recording the changes with a video camera.

2a. The gravity effect was first noticed with a small flat iron plate. (7x8 cm^2 in area, 0.72 mm thick and a weight of 37.82 gm). As is shown in the Figure 1, the plate surface is on the xy-plane and the y-axis is the vertical direction. When it was rotated 360 deg about z- axis at the center perpendicular to the plat (xy plane), it was giving different readings at different angles with a sensor attached at one corner as shown.

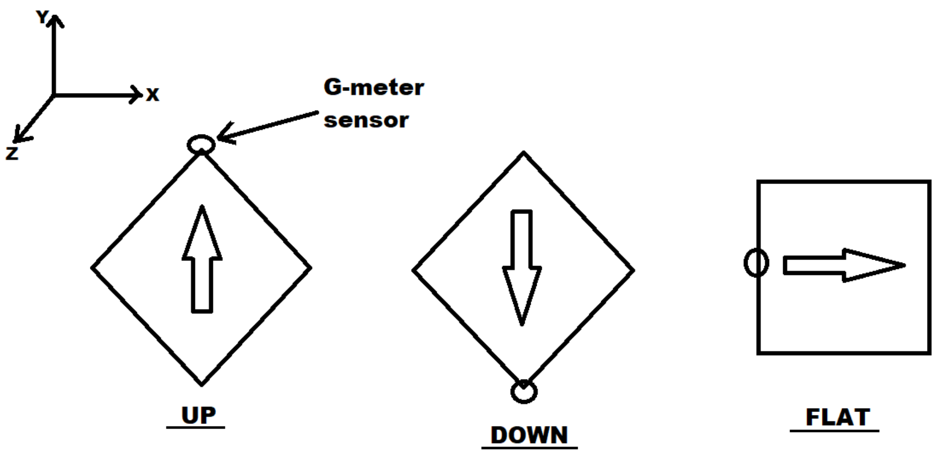

Figure 1. Three positions of the iron plate. The y-axis is the vertical direction.

The 'up' and 'down' are referred to the vertical directions, therefore the falling of the magnetic charges may be observed, if any. However, in the ‘flat’ or horizontal position, there is no movement due to gravity, and there is very little changes in the readings as to be expected.

It was a surprised observation at first. However, it was confirmed with many other samples of different shapes and sizes. In the following, we will give three more examples to illustrate how one can deduce some useful numbers for the effective mass and give some of the influencing factors which effected the movement of the falling magnetic charges.

2b. An Iron hammer with wooden handle:

As showing in Figures 2 & 3, three positions are as follows: the wooden handle is the rotating axis (along the x-axis). The vertical up and down positions are along the y-axis. When it is in 'up' position (ie A on top) one can measure the changes of magnetic charges due to the gravity by reading of Gauss meter at C. Similarly, in the 'down' position (ie C on top), the sensor is located at A. The 'flat' is when A and C both are on the horizonal-plane.

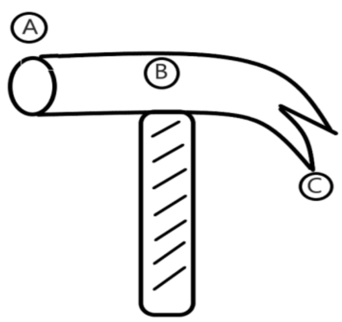

Figure 2. The top portion of a hammer (with a wooden handle). The distance from A to C is approximately 14 cm.

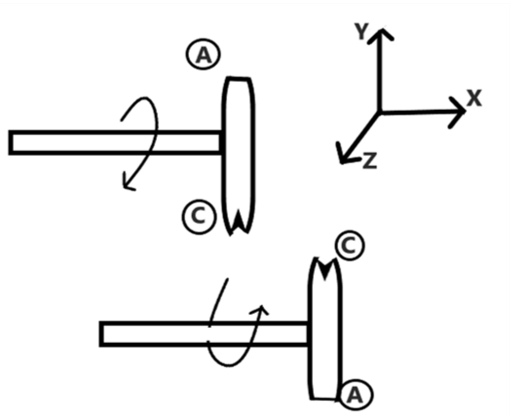

Figure 3. The locations A and C are the same as in figure 2. The y-axis is in the vertical direction.

The readings which showing the changes due to the gravity are larger at A and C , but less at the middle location. Also, when C is up, the reading is higher than when A is up. Maybe it is due to the splitting of the hammer end, or the sharper end of this structure. In any case it is interesting to see a larger effect in this small but 3-D sample in comparison with the 2-D sample (As in the case 2a above) .

The results are reproducible. However, due of the complicated geometry of the hammer (and the sample 2c below), we are not going to analyze the data for the effective mass in this sample.

2c.The cast Iron cooking pot: (Average thickness; 0.45 cm, weights 15.4 kg)

The sensor was attached near the end of the larger circular side as shown in the Figure 4. The pot was moved in three positions: namely up (ie when the sensor is at the lower side), flat, and down. The readings were taken in each position accordingly. The results are showing in Figure 5. One noticed that from 'up' and 'flat' did not have many changes, but there are larger changes from 'flat' to 'down' position. This indicated that the sized made all the difference in this sample. The larger surface which made the movement of the magnetic charges much easier in comparison with smaller narrow handlebar. This is mainly due to the fact that the magnetic charges move mainly on the surface. Also, the sensor is nearer to the large surface than the narrow handlebar which made it easier to catch the magnetic charges.

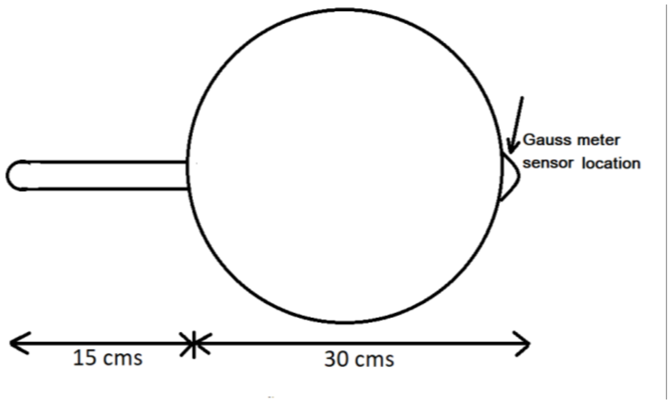

Figure 4. The shape of a big cast iron pot.
The sensor is located at the right end of the pot.

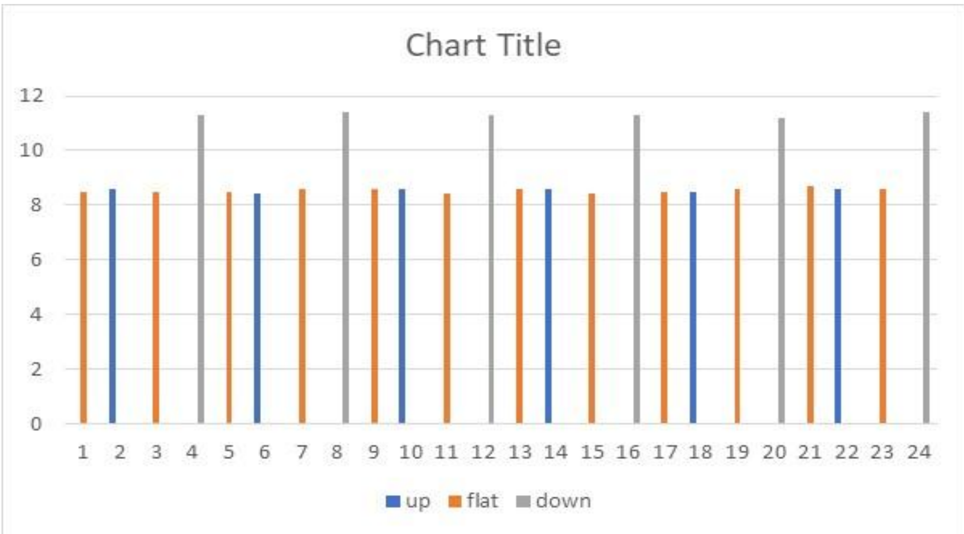

Figure 5. The results of the sensor readings (in Gauss) with different settings.
The x-axis here is the sequence of operations in turning the pot from
one position to the other.

2d. An Allen wrench; (dimensions: 15 cm in length, 5mm diameter and weights 36.77gm). As shown in figure 6, the small PM below has the polarity S under and N on top. This will induce N (q_2) near the top (say 3 cm below the top). This will interact with the N (q_1) there, to be ready to fall due to gravity. This will slow down (and/or cause less magnetic charges) for falling because of the repulsive force between the same magnetic charges. The result is to reduce the total falling charges at the bottom. (The interaction at the bottom is assumed to be small and can be neglected). The values of the magnetic charges of q_1 were independently determined.(using Guess theorem, for example see [11]). But the value of q_2 can only be estimated, it depends on the distance of the lower PM from the sample as well as the values of the PM nearby.

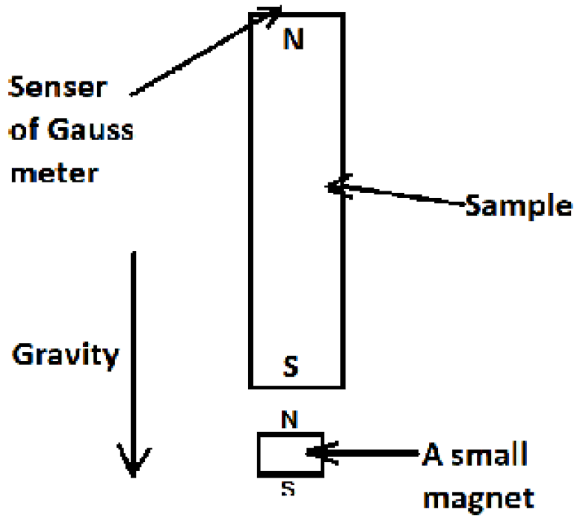

Figure 6. The sample is a hexagonal shape Allen wrench which is in vertical position. The sensor can be attached either at the top or the bottom of the sample.

The counterbalance of the external magnet was used to estimate the forces which drive the magnetic charges due to gravity as follows.

$$F = m_q \times g = \frac{\mu_r}{4\pi} \times \frac{q_1 \times q_2}{r^2}$$

Where $q_1 \cong 4(A-m)$; $q_2 \cong 2(A-m)$; $r = 3cm$; $g = 9.8\, m/sec^2$

$\mu_r = 500 \text{ x } \mu_{0,}$ $\mu_0 = 4\,\pi \text{ x } 10^{-7}$ N/A^2

Therefore, we have: $m_q = 5.0\text{x } 10^{-2}$ kg

With n=number of magnetic charges/(A-m) involved in the falling ≅ 3.0 x 10^9 [12]

$$\therefore M_{eff} = \frac{m_q}{n} \cong 1.6 \times 10^{-11}\, kg$$

It should be noted that in a magnetic material, the μ is different from that in vacuum. Therefore, the μ_r for the material of the sample was used in the calculation.

The result for the effective mass of a monopole is approximately 1.6x 10^{-11} kg, which is comparable with other theoretical estimates [6]. Due to many uncertainties, only order of magnitude can be established.

3. RESULTS AND DISCUSSIONS

The observations for the changes in the magnetic readings when the sample was turned vertically up, down, and up again, were repeated several times through careful repeated measurements of many days, some consistent results were obtained.

The time it took the magnetic charges to fall through the whole sample were also recorded. This can be used to estimate the average velocity the fall of magnetic charge particles. (Depending on the sample, the velocity in the sample 2d is approximately 1-0.5 mm/sec).

The slow movement of this magnetic charge cluster may be due to several reasons. One can speculate some possible causes, since the real causes are rather unknown. One of the reasons could be the magnetic clusters have to travel on the surface of the sample. The other is the magnetic clusters must go through the domain structure in the sample, which may involve complicated interactions with spin and charges in the domain. In fact, it was pointed out by Kittel and Manuliu [10]. It will take about 50 ev of energy at 300 Å from the surface for the interactions of magnetic domain with the monopoles in Iron. However, it is not known how far from the surface the magnetic particles move due to gravity in our experiment. Hence more experiments are needed to understand the mechanism of the interesting and important gravitational effect on the magnetic charges.

Another puzzling question is that only nearly 20 % of the magnetic charges are involved with the falling due to gravitational force. Why are the rest of the charges not moving much at all? Is it because the gravitational force is too weak, or some other mechanism which make them rather immobile? Even though some of them were moved freely in the induction process.

One noticed that there were errors in the readings of the Gauss meter whenever the sensor probe is moved to a different position. This can partially be eliminated by firmly attached to the magnetic material in question.

4. CONCLUSIONS

From the measurements of falling magnetic cluster due to the gravitational force which made the change in the magnetic field large enough to be measurable. The measurements were reproducible if some cares were taken in the process of measuring with a Gauss meter. The value estimated approximately 1.6 x 10^{-11} kg for the effective mass of a monopole is comparable with other theoretical works [6]. The values of q/m_q were estimated to be approximately 50 (A-m/kg) for the unit magnetic charges (which is much smaller, due to its heavy mass, in comparison with the value of e/m_e of 1.76 x 10^{11} C/kg for the unit electrons). More work should be done with a sensitive magnetometer and using more sensors along the sample to obtain a better number for the effective mass of the magnetic charges.

One other conclusion here is that the gravitational force acting on a magnetic cluster is a definitive proof for the existence of the magnetic charges (or magnetic monopoles) which are falling with a single polarity. It is understood that magnetic clusters are collections of a very large number of magnetic monopoles and are mainly classical entities.

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