Natural Sciences and Advanced Technology Education *Volume 31 Number 4, 2022* *Обучение по природни науки и върхови технологии*

https://doi.org/10.53656/nat2022-4.01

Education: Theory and Practice

MAGNETIC PROPERTIES

Sofija Blagojević, Lana Vujanović, Andreana Kovačević Ćurić
General Gymnasium of the Catholic School Centre in Banja Luka
Bosnia and Herzegovina

Abstract. Here will be explained and showed what magnetic properties and magnetism it self are. The experiments are based on showing how different materials work in magnetic field or what happened to them in magnetic field. The magnetic properties will be shown on aluminium, pyrolytic spitz, apple and matches. Further explanations of these magnetic properties and phenomenon are in the continuation of this document. All the experiments will include neodymium magnet. Neodymium magnet is type of rare-earth magnet. It is a permanent magnet made from an alloy of neodymium, iron, and baron to form the tetragonal crystalline structure. Neodymium magnet can very easily be demagnatize and that can be permanently on temprature of 80 celcius or even less. This temeprature is also called "The Kiri's temperature". We need to be very careful when using this magnet because it can get demagnetize.
Keywords: magnetism; magnetic field; magnetic properties

1. Introduction

Magnetism is the force exerted by magnets when they attract or repel each other. Magnetism is caused by the motion of electric charges. Every substance is made up of tiny units called atoms[1)]. Magnetic Field is the region around a magnetic material or a moving electric charge within which the force of magnetism acts. Magnetic fields can be illustrated by magnetic flux lines. At all times, the direction of the magnetic field is shown by the direction of the magnetic flux lines[2)]. The magnetic property of a material is the atomic or subatomic response a material to an applied magnetic field wherein the electron spin and charge create a dipole moment and a magnetic field[3)].

Paramagnetism refers to this defintion: In materials whose atoms have unpaired electrons, the magnetic moments of individual electrons cannot fully cancel out, and so the atoms are left with a resultant magnetic moment. However, the magnetic moments of atoms are aligned in random directions, so the material as a whole does not exhibit magnetism. However, if such a material is placed in an external magnetic field, then the magnetic moments of individual atoms can then align with the external magnetic field, causing the material to become magnetised. The magnetic field produced by paramagnetic materials points along the same direction as the external magnetic field. The material exhibits magnetism only as long as it is inside an external magnetic field. If the external magnetic field is switched off, then the material loses its magnetisation[2)].

Ferromagntism refers to this definition: Atoms that make up ferromagnetic materials have unpaired electrons in their atoms so each atom has a net magnetic moment. The magnetic moments of nearby atoms tend to become aligned, creating different regions (called domains) in the material, where magnetic moments due to individual atoms are aligned. However, different domains may still have their magnetic moments pointing in different directions. When a ferromagnetic material is placed inside an external magnetic field, the different domains inside the magnetic fields all align with the external magnetic field[4)].

Diamagnetism is the weakest of the three different types of magnetism. Therefore, if a material is paramagnetic or ferromagnetic, its diamagnetic effects are masked by these other two types of magnetism. In diamagnetic materials, magnetic moments of each of the individual electrons in the material gets cancelled out. When a diamagnetic material is placed under a magnetic field, the material produces a magnetic field that opposes the external magnetic field. As a result, the material gets repelled by the external field. Almost all materials are diamagnetic[3)].

The main difference between diamagnetism, paramagnetism, and ferromagnetism is that diamagnetism refers to a type of magnetism which forms in opposition to an external magnetic field and disappears when the external field is removed; paramagnetism refers to a type of magnetism that forms along the direction of an external magnetic field and disappears when the external magnetic field is removed; ferromagnetism refers to a type of magnetism in materials which forms along the direction of the external magnetic field and can remain when the external magnetic field is removed.

2. Magnetic Properties of Materials[5)]

Property 1: Intensity of magnetization

Intensity of Magnetization stands for the extent to which a specimen is magnetised when placed in a magnetising field. In other words, the intensity of magnetisation is defined as the magnetic dipole moment developed per unit volume when a magnetic material is subjected to magnetizing field[6)].

$$I=\frac{M}{V}, \text{ where}$$

I – intensity of magnetization; *M* – the magnetic moment; *V* – the volume.

Property 2: Magnetic flux

Magnetic flux is a measurement of the total magnetic field which passes through a given area. It is a useful tool for helping describe the effects of the magnetic force on something occupying a given area. The measurement of magnetic flux through the chosen area[7]. Figure 1 shows a task about magnetic flux. This figure represents how magnetic flux works in prism and what is the formula for magnetic flux. Figure 2 shows a graphic representation of magnetic flux.

$$\phi_B = B*A*\cos(\theta), \text{ where}$$

B – magnetic field; *A* – area perpendicular to the magnetic field B; θ – is the angel between the magnetic filed lines and the normal (perpendicular) to A.

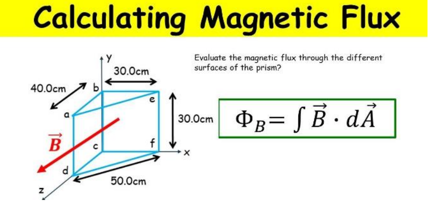

Figure 1. Formula for magnetic flux

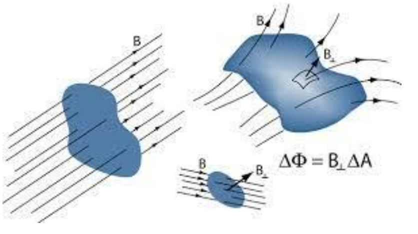

Figure 2. Graphic representation of magnetic flux

Property 3: Magnetic induction

Electromagnetic induction is a process in which a conductor is put in a particular position and magnetic field keeps varying or magnetic field is stationary and a conductor is moving. This produces a Voltage or EMF (Electromotive Force) across the electrical conductor. [2]

The rate of change in magnetic flux gives rise to an induced voltage, a relationship called Faraday's Law, $V_{induced}$ = - *DFB/Dt.* If all along the border of this page a wire was placed then this induced voltage would have the same effect as if we connected the wire to a battery of voltage, $V_{induced}$.

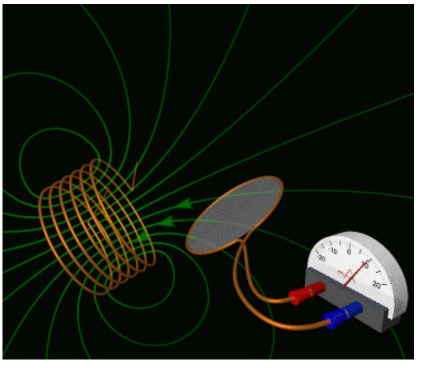

Figure 3. Magnetic induction and how it works with wire and electromagnet or static magnet

In the case of a closely wound coil of N turns, the change of flux associated with each turn is the same and so the total induced emf or magnetic induction is given by the formula:

$$e=N\frac{d\phi}{dt},$$ where

e - (Instantaneous) induced voltage in volts; *N* – number of turns in wire coil

(coil straight = 1); ϕ – magnetic flux in Webers; *t* – time in seconds

Property 4: Magnetic susceptibility

Magnetic susceptibility is the degree to which a material can be magnetized in an external magnetic field. If the ratio between the induced magnetization and the inducing field is expressed per unit volume, volume susceptibility χ is defined as[8]:

$$\chi_m=\frac{I}{H},$$ where

χ – magnetic susceptibility of a substance; *H* – magnetizing force; *I* – intensity of magnetization.

Property 5: Magnetic permeability

Magnetic permeability is a material property that describes the change in the magnetic field inside a material compared with the magnetization field in which it is located. In other words, it shows how easily a material is affected by an induced magnetic field[2]:

$$\mu=\frac{B}{H},$$ where

μ – magnetic permeability; *B* – magnetic field; *H* – magnetizing force.

A higher susceptibility implies that the material is more susceptible to the field and hence can be easily magnetized. Magnetic permeability is a property of the material that characterizes the amount of magnetizing force *H* that a material experiences under the influence of an applied magnetic field *B*.

Expirements and explanations

1st EXPERIMENT: Magnetic properties in matches

This experiment contains wood matches and neodymium magnet. When the magnet is brought closer to unlit matches - the magnet does not attract matches. By lighting the matches and letting them burn almost to the end and turn them off, the magnet will attract the burned matches to itself. Why is this happening? When a monodomain ferromagnetic particle is heated to temperature above the critical one the ferromagnetic order parameter is destroyed. Then after cooling the particle can go in some other state with different permanent magnetization. The heating of a compass arrow and destruction of its magnetization by feuer. With a different and changed electronic configuration, some substances get magnetic properties. This happened to the matches and burnt matches could create a magnetic field between themselves and the magnet. This experiment shows and explains phenomenon and magnetic property called paramagnetism. As previously mentioned, electrons re-organize and align with the magnet, and form a magnetic field. What also happens is ferromagnetism, because the magnet attracts the matches and everything mentioned previously points and proves the phenomenon called ferromagnetism.

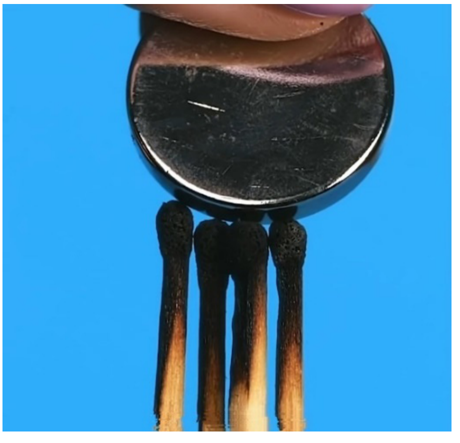

Figure 4. The final look of the experiment. Burnt matches stick to the magnet

To bolster this theory and explanation, here are mentions and explanations about pyrolytic graphite spikes and ordinary graphite spikes and how can they, while being in magnetic field, form either paramagnetism or diamagnetism phenomenon. Pyrolytic graphite spike is a material similar to graphite, but with some covalent bonding between its graphene sheets as a result of imperfections in its production[2)]. Pyrolytic spike is man-made and is thought not to be found in nature. Generally it is produced by heating a hydrocarbon nearly to its decomosition temperature, and permitting the graphite to crystalize (pyrolisis). One method is to heat synthetic fibers in a vacuum. Another method is to place seeds on a plate in the very hot gas to collect the graphite coating. It is used in high temperature applications such as missile nose cones, rocket motors, heat shields, laboratory furnaces, in graphite – reinforced plastic, coating nuclear fuel particles, and in biomedical protheses. Some graphite spikes are made out of pyrolitic carbon and because of that, they can form a magnetic field between there selfs and magnet. Spikes made out of pyrolitic carbon form a diamagentic field betwwen them self and magnet, whilst other spikes made out of some other form of carbon, form a paramagnetic filed between them self and magnet.

2nd EXPERIMENT: Magnetic properties in apple

This experiment contains apple and neodymium magnet. It can also contain wooden stand and a piece of thread to hang the apple on that. If we bring the magnet closer to the apple, we will see that it repels. The apple has in its composition an element that has low magnetic properties and therefore attracts or repels from the magnet. Also, sometimes one magnet is small, and the effect cannot be seen. If that happens, by adding more smaller magnets to the bigger one, the results will be seen. Apples are field with water, and they do have some percentage of water in themselves. Considering the consistence of water, we can see that apple itself can form a small diamagnetic field between itself and magnet. Apple is repelled by magnet, but the movements are exceedingly small, usually because of a size of an apple or a size of a magnet (apple can usually be too big and magnet can be too small to show some big movements of an apple).

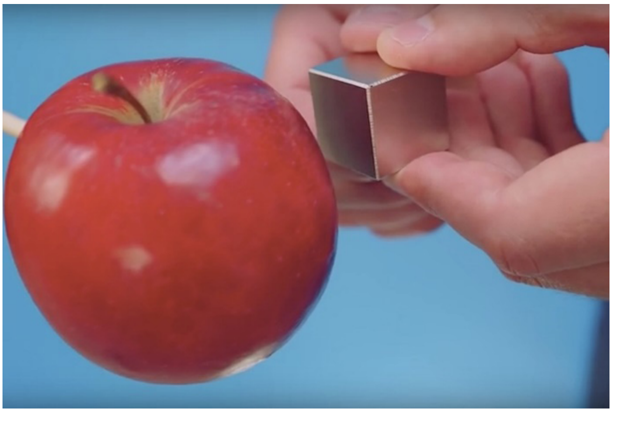

Figure 5. The experiment with neodymium magnet and apple. Apple repels from the magnet because of previous explanations

3rd EXPERIMENT: Magnetic properties in aluminum foil

Aluminum is a chemical element with the symbol *Al* and atomic number 13. Aluminum has a density lower than those of other common metals, at approximately one third that of steel. It has a great affinity towards oxygen and forms a protective layer of oxide on the surface when exposed to air. Aluminum visually resembles silver, both in its color and in its great ability to reflect light. Aluminum is very weakly paramagnetic, meaning it slightly amplifies external magnetic fields passing through it, but this effect goes away when the external magnetic field is removed. The experiment is done by crumpling of aluminum foil, hanging it on a string and waiting for it to come to a standstill. When the ball was completely calm, bring the magnet closer to the ball and see the results, because the aluminum ball moved a little. The shift was not drastic for the above reasons. As we all know, aluminum's electronic configuration is: $1s^2 2s^2 2p^6 3s^2 3p^1$. One electron gets canceled out and because of unpaired electron in aluminum, magnetic field can be formed between aluminum and magnet. In Fig. 6 the magnet attracts the aluminum, but in this case because of indifference of sizes, it looks like it's otherwise (the can attracts the magnet), but it's not.

Figure 6. The experiment with aluminum can and neodymium magnet

Conclusion

The main purpose of these experiments is to visually prove how magnetic properties and phenomenon's can be showed with materials we have at home. Everything we used for these experiments is in an every- day usage. These experiments prove and show how varied materials and substance react with magnet and how magnetism really works and what happens when there is repletion or attraction to the magnet. This paper includes explanations and proofs of paramagnetism and diamagnetism. These magnetic properties are shown through experiments with aluminum foil, apple, pyrolytic graphite spikes and neodymium magnet.

NOTES

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✉ **Sofija Blagojević, student**
General Gymnasium of the Catholic School Centre
Srpska 30, Banja Luka 78000
Bosnia and Herzegovina
E-mail: sblagojevic06@gmail.com

✉ **Lana Vujanović, student**
General Gymnasium of the Catholic School Centre
Srpska 30, Banja Luka 78000
Bosnia and Herzegovina
E-mail: lanavujanovic1@gmail.com

✉ **Andreana Kovačević Ćurić, mentor**
ORCID ID: 0000-0002-1773-6765
General Gymnasium of the Catholic School Centre
Srpska 30, Banja Luka 78000
Bosnia and Herzegovina
E-mail: andreanakc88@gmail.com