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Dipole and poleless magnetic fields

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Abstract

This paper compares the magnetic fields of linearly moving charges with those of orbit ally moving charges. With simple qualitative experiments are shown the structure of the magnetic fields created by these movements. The concept of a pole less magnetic field is introduced, which is created by linear and inertial moving positive and negative charges as well as by currents in wires. A distinction is made between a dipole magnetic field and a poleless magnetic field. It is proved that the dipole magnetic field is not homogeneous, but is a sum of two magnetic fields that are mutually opposite in electrical and force properties. The poleless magnetic field is only one part of the dipole magnetic field. It is the main magnetic field and reason for existence of the dipole magnetic field. It has nothing to do with the concept of a magnetic monopoly.

Keywords

Permanent magnets, electromagnets, magnetic field, magnetic poles, magnetic lines of force, magnetic induction, magnetic induction vector, electric field, electric current, movement of charges, poleless magnetic field, dipole magnetic field.

I. Introduction

There are two main ways electric charges move:

- inertial movement of charges, in which no forces act on them and they move linearly and rectilinearly, with uniform spin or as a combination of both movements.

- movement of charges under the influence of forces, in which they move curvilineal, accelerating, retarding, uniform or non-uniform, orbital or with variable spin. The most typical are inertial, orbital and spin movements[1,2,3].

Examples of inertial motions are the flows of alpha and beta particles in the radioactive decay of matter, the flows of electrons, protons and various types of ions in outer space, emitted by stars and galaxies, as well as the generation of charges arising from transient processes in solids and fluids states of matter[4,5].

Examples of orbital spin motions of charges are the motions of electrons in atoms under the influence of Coulomb attraction, or the flow of current in closed wire loops, representing the drift of multiple electrons.

There is a major accepted hypothesis that moving charges are the cause of a magnetic field. In connection with the orbital-spin movements of charges or their circular movement in wires, we are familiar with two main groups of carriers of the magnetic field: - permanent magnets and electromagnets[6,7]. Permanent magnets or wire electromagnets through which current flows create a dipole magnetic field with two poles - north and south. Unlike poles attract and like poles repel. The environment in the space around the magnet is characterized by the value magnetic permeability μ, which connects the magnetic induction $\vec{\boldsymbol{B}}$ with the intensity of the magnetic field $\vec{\boldsymbol{H}}$ in the ratio $\mu = \vec{\boldsymbol{B}} \ / \ \vec{\boldsymbol{H}}$. In an air environment and room conditions, a sufficiently acceptable for the exposition equal and homogeneous magnetic permeability[6,7,8]. For this we will work with the magnetic induction $\vec{\boldsymbol{B}}$.

In addition to the described known dipole magnetic field caused by orbital spin motion of charges and flow of currents in circular wire loops, we will prove that there is also a poleless magnetic field, which is generated by the inertial motion of charges or by their motion in a wire under the influence of electric field.

In the experimental part of the exposition, the air resistance arising during the movement of the magnets is neglected.

II. Dipole magnetic field

Magnets create a dipole magnetic field around them, which is characterized by magnetic lines of force with the same properties, which have neither beginning nor end. According to Maxwell's third equation

Div $\vec{\boldsymbol{B}} = 0$ (1),

the magnetic induction $\vec{\boldsymbol{B}}$ is the total sum of the vectors passed as a tangent at arbitrary points of the force lines with a direction from the north to the south pole of the magnet[9, 10, 11, 12].

In other words, if we assume that the field lines are **n** in number, where **n** is an arbitrarily large natural number, then to any point of an arbitrarily chosen magnetic field line **i** we can pass a tangent vector $\vec{\boldsymbol{b}}_{\boldsymbol{i}}$ with a direction from the north to the south pole , where **i =1, 2, …, n**.

Therefore, the sum of these vectors is the magnetic induction:

$$\vec{\boldsymbol{B}} = \sum_{i=1}^{n} \vec{\boldsymbol{b}}_{\boldsymbol{i}} \qquad (2)$$

With uniform and isotropic magnetic permeability, the density of magnetic field lines, i.e. the magnetic induction $\vec{\boldsymbol{B}}$ decreases symmetrically away from the center of the pole, as shown in Fig.1A1.

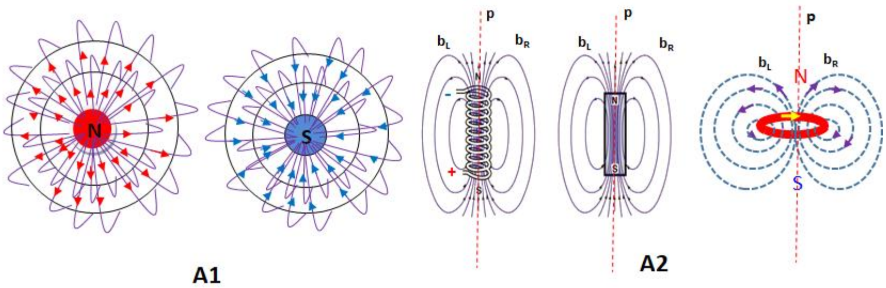


Fig.1 *A1- Outgoing magnetic field lines from the North Pole and incoming lines of force at the South Pole, viewed from the side of the poles*

A2 - Projections in the sheet plane of the magnetic field lines of solenoid, of permanent magnet and of circular current

The magnetic field lines exit symmetrically from the north pole and enter symmetrically at the south pole. In any plane who include the line **p** passed between the centers of the poles - a polar plane, the tangent vectors $\vec{\boldsymbol{b}}$ to any point of the lines of force are directed not only from the north to the south pole, but are also diametrically opposite, as shown in Fig.1A2 where the pole plane coincides with the plane of the sheet.

Since according to (2) the total number of field lines is **n**, the number of pole planes is

$$j = \frac{n}{2} \qquad (3)$$

Therefore, relative to any polar plane, the space occupied by magnetic field lines is divided into two half-spaces:

- A half-space in which a tangent vector $\vec{b}_R$, which is directed from the north to the south pole and clockwise, can be drawn to any point of the magnetic field lines belonging to it.
- Accordingly, a half-space in which a tangent vector $\vec{b}_L$, which is directed from the north to the south pole and directed counterclockwise, can be passed to each point of the magnetic field lines belonging to it.

For definiteness, the half-space occupied only by magnetic induction vectors $\vec{b}_R$ will be called $\vec{b}_R$ half-space or $\mathbf{b_R}$ magnetic field, and the half-space occupied only by magnetic induction vectors $\vec{b}_L$ will be called $\vec{b}_L$ half-space or $\mathbf{b_L}$ magnetic field.

The magnetic induction of the $\vec{b}_R$ half-space is the sum of the vectors $\vec{b}_R$:

$$\overrightarrow{B_R} = \Sigma\, \vec{b}_R \qquad (4)$$

The magnetic induction of the $\vec{b}_L$ half-space is the sum of the vectors $\vec{b}_L$:

$$\overrightarrow{B_L} = \Sigma\, \vec{b}_L \qquad (5)$$

Therefore, the total magnetic induction in the space around the magnet is:

$$\vec{B} = \overrightarrow{B_R} + \overrightarrow{B_L} \qquad (6)$$

The changes in magnetic and electric fields, the movement of charges, the flow of current, and the interaction of permanent magnets and electromagnets with wires, as well as their relative motions relative to each other, are covered by Maxwell's second and fourth equations.

According to Faraday's law of electromagnetic induction, described in Maxwell's second equation, the circulation of the electric field $\vec{E}$ in a closed surface $\vec{S}$ is equal to the rate of change of the magnetic field $\vec{B}$ penetrating this surface[3,14]. In other words, the changing magnetic field gives rise to an eddy electric field.

$$\mathbf{Rot}\, \vec{E} = -\frac{\partial \vec{B}}{\partial t} \qquad (7)$$

In the particular case, when the closed surface $\vec{S}$ is a closed wire loop, any change in the magnetic field inside this loop is converted into an electric current flowing along the wire.

Here we should note that only magnetic field lines crossing the axis of a wire loop or a straight wire when the magnetic flux changes generate electromotive force (EMF) in it. Magnetic field lines coinciding with the axis of the conductor or parallel to it do not generate an EMF.

Conversely, any current **j** flowing in a wire loop and the change in electric induction **D = εE** give rise to a vortex magnetic field $\vec{B}$, according to Maxwell's fourth equation:

$$\mathrm{Rot}\,\vec{B} = \frac{j}{\varepsilon_0 c^2} + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}\,, \qquad (8)$$

where **ε** is the dielectric permittivity of the medium, **c** is the speed of light, and $\vec{E}$ is the electric field[15].

In equations (1) and (7) it is considered that all magnetic lines of force of the magnetic induction

$\vec{B}$ have the same force impacts and the same contribution to the generated EMF in a wire loop due to the change of the magnetic induction.

The electric current and the change of the electric induction **D = εE** in (8) generate the magnetic induction $\vec{B}$, where all magnetic field lines have the same properties.

Is this so? Should in equations (1), (7) and (8) $\vec{B}$ be replaced by $\vec{B_R} + \vec{B_L}$ according (6)?

III. Description of the experimental setup for relation verification (7)

A dense cylindrical neodymium magnet of length **l << h** and diameter **d < l** is allowed to fall freely into a plastic guide tube of height **h** fixed perpendicularly and immovably to a wooden table. The poles of the magnet are located on its long side. The magnet falls on a wooden table placed perpendicular to the axis of the cylinder, covered with shock-absorbing rubber. At the moment of contact with the surface, the velocity $V = \sqrt{2gh}$ is the same for all experiments[16,17], where **g** is the ground acceleration. The drop point is always the intersection of the pipe axis with the plane of the table top - point **c**. Fixed current loops[18] of different sizes can be placed on the table in a different way in the form of a rectangular wire frame with different side lengths ab = a_1b_1 and aa_1 = bb_1. The normal unit vector **n** of the contour is directed against the direction of incidence of the magnet. The wire diameter is much smaller than any dimension of the magnet. The ends of each fixed current loop are connected to a

USB oscilloscope with a trigger to measure the resulting EMF [19,20] as a single pulse and record it in the memory of a computer. Measures are taken so that the magnetic field of the moving magnet does not affect the oscilloscope.

Typical cases:

1. The motionless current loop has dimensions $ab = a_1b_1 >> l$ and $aa_1 = bb_1 >> l$. The falling magnet is oriented with the north pole down, where its pole axis **p** crosses the surface at point **c**.

In this case, the dimensions ab and aa_1 are determined so that when the magnet falls at point **c** - the center of the loop and has a speed **V**, the resulting EMF in it is less than the permissible error. In other words, each side of the loop is far enough away from the magnet as shown in Fig.2A1.

Results and discussion

Here we have a change in magnetic flux $\boldsymbol{\Phi} = \vec{\boldsymbol{B}}.\vec{\boldsymbol{S}}$ in the current loop a, a_1, b_1, b with area $\vec{\boldsymbol{S}}$ by increasing the magnetic induction $\vec{\boldsymbol{B}}$, but no EMF occurs[21,22].

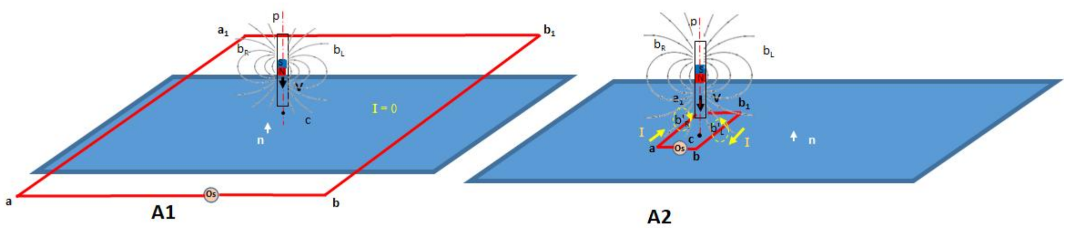


Fig.2 *A1 – An increase in magnetic induction in a wire loop, in which no EMF and current in it occur.*

A2 - Increase of magnetic induction in a current loop where

a maximum EMF and a maximum circuit current occur.

The change in the magnetic flux $d\Phi/dt$ is significant only around the magnet, and it is far enough away from any part of the conductor. In this situation, EMF does not occur. The current flowing **I** along the loop is zero.

2. The motionless current loop has dimensions $ab = a_1b_1 > l$ and $aa_1 = bb_1 > l$. The falling magnet is oriented with the north pole down, where its pole axis **p** crosses the surface at point **c**.

The size of the loop is only slightly larger than the diameter of the magnet **d**.

The frame is positioned so that the magnet falls at point **c** - the middle of the loop. This is shown in

Fig. 2A2. The change in magnetic induction $\vec{B}$ covers the entire loop - aa_1, a_1b_1, b_1b, ba[23,24].

Results and discussion

At the moment of contact of the magnet with the surface, the measured EMF has a maximum value. It is a sum of the individual EMF in the sections of the contour aa_1, a_1b_1, b_1b, ba. With respect to any arbitrarily oriented polar plane in the two half-spaces separated by it, the vectors of the magnetic induction $\vec{B}$, passed as tangents to the magnetic force lines, in addition to being directed from the north to the south pole of the magnet, also have opposite directions. The vectors $\vec{B}_R$ in the $\vec{b}_R$ half-space are clockwise and the vectors $\vec{B}_L$ in the $\vec{b}_L$ half-space are counterclockwise. The currents caused by them form the total circular current **I** clockwise. This current generates secondary magnetic fields $\mathbf{b'_R}$ and $\mathbf{b'_L}$, where the direction of the tangent vectors $\vec{B'}_R$ and $\vec{B'}_L$ follow the direction of the tangent vectors of the primary magnetic fields $\mathbf{b_R}$ and $\mathbf{b_L}$. The magnetic induction $\vec{B}'$ is oppositely directed to that of $\vec{B}$, according to Lenz's rule.

3. The motionless current loop has dimensions $ab = a_1b_1 >> l$ and $aa_1 = bb_1 >> l$. The falling magnet is oriented with the north pole down, where its pole axis **p** crosses the surface at point **c**.

The dimensions are identical to those of Fig. 2A1, but the frame is positioned so that the magnet falls as close as possible to the middle of one of its sides at point **c**, very close to aa_1 or bb_1. This is shown in

Fig. 3 A1 and Fig. 3 A2. Since we have chosen the dimensions of the contour large enough, we can consider that the variation of the magnetic induction $\vec{B}$ is only in section aa_1 or only in section bb_1. According to Fig.3 A1, the section aa_1 is crossed only by the magnetic field $\mathbf{b_R}$, creating a magnetic induction $\vec{B}_R$.

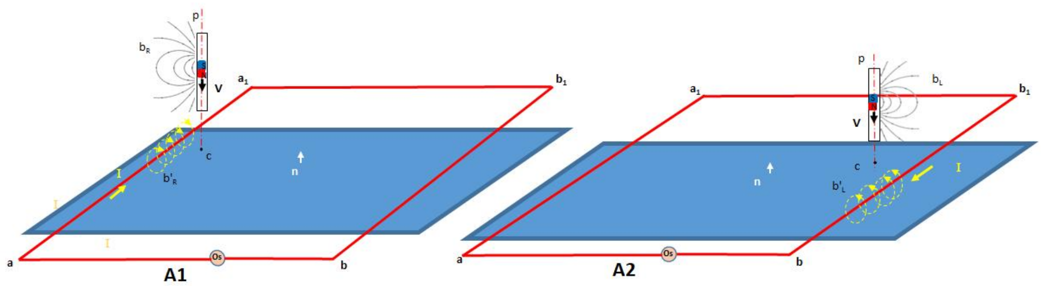


Fig.3 *A1 – Increase of the magnetic induction in a current loop, in which EMF occurs only in section aa_1 and corresponding circular current **I** clockwise*

*A2 – Increase of magnetic induction in a current loop, in which EMF occurs only in section bb_1 and corresponding circular current **I** clockwise*

According to Fig. 3 A2, the section bb_1 is crossed only by magnetic field lines oriented counterclockwise - half of the magnetic field lines with tangent vectors of the magnetic induction $\vec{B}_L$.

Results and discussion

The resulting EMF **E** is generated by the change of the magnetic induction $\vec{B}_R$ in the section aa_1 or the magnetic induction $\vec{B}_L$ in the section bb_1. These EMFs create a current **I** in the clockwise loop. We can consider the sections of the frame aa_1 or bb_1 as a straight wire located perpendicular to the magnetic induction vector. From Faraday's law of electromagnetic induction, according to (7), applied to a straight wire, it follows that the magnitude of the EMF **E** generated in the circuit is:

$$\mathbf{E} = \mathrm{L}\vec{B}_R\mathrm{V} \quad OR \quad \mathbf{E} = \mathrm{L}\vec{B}_L\mathrm{V} \qquad (9)$$

where **L** is the length of the sections aa_1 or bb_1 of the contour that are crossed by the magnetic field lines of magnetic induction $\vec{B}_R$ or $\vec{B}_L$, and **V** is the speed of the magnet at point **c**.

The current in the loop is:

$$\mathrm{I} = \frac{E}{R} \qquad (10)$$

where **R** is the resistance of the wire loop [25,26].

The current **I** creates a secondary magnetic field, which in the section aa_1 is described by the vector $\vec{B'}_R$, and in the section bb_1 is described by the vector $\vec{B'}_L$.

The current **I** in section aa_1 generated by $\vec{B}_R$ is in the direction from us to the sheet and the current **I** in section bb_1 generated by $\vec{B}_L$ is in the direction from the sheet to us. Therefore, in equation (6), the two components of the magnetic induction generate opposite EMFs, and it cannot be claimed that the magnetic induction in (1) is a sum of magnetic lines of force identical in properties.

4. The motionless current loops have dimensions $ab = a_1b_1 >> l$ and $aa_1 = bb_1 >> l$. The falling magnet is oriented with the north pole down, where its pole axis **p** crosses the surface at point **c**.

These current loops are identical to those in Fig.3, but positioned so that the magnet falls at point **c** - the middle of aa1 or the middle of bb_1, with the pole axis **p** crossing the conductor axis. Then the conductor sections aa_1 or bb_1 are simultaneously crossed by the magnetic field lines of the oppositely directed but equal-module vectors $\vec{B}_R$ и $\vec{B}_L$.

Results and discussion

Regardless of the change in $\vec{B}_R$ и $\vec{B}_L$ no current **I** occurs. This is shown in Fig.4A1 and Fig.4A2.

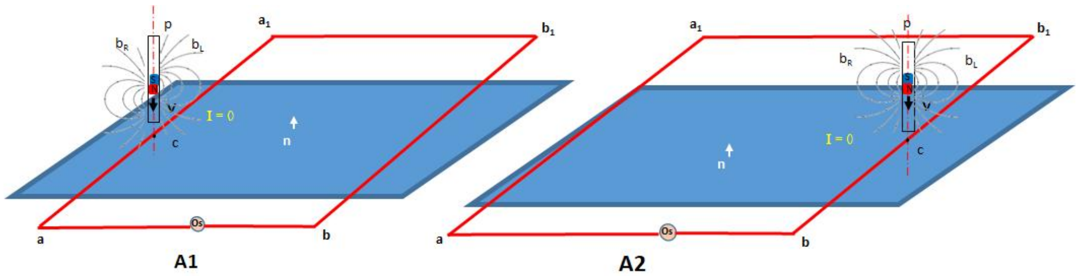


Fig.4 *A1 - Increase in magnetic induction only in section* aa_1 *when the pole axis of the magnet* ***p*** *crosses the axis of the conductor*

A2 - Increase in magnetic induction only in section bb_1 *when the pole axis of the magnet* ***p*** *crosses the axis of the conductor*

As a result of the simultaneous increase of the magnetic inductions $\vec{B}_R$ и $\vec{B}_L$, opposite currents arise in these sections, which mutually compensate. The total current is zero. Therefore:

$$\vec{B}_R = -\vec{B}_L \qquad \textbf{(11)}$$

Moreover, the magnetic induction modules in this particular case satisfy the equation:

$$\mathbf{B_R = B_L =} \frac{B}{2} \qquad \textbf{(12),}$$

where **B** is the modulus of the total magnetic induction $\vec{B}$.

5. The motionless current loops have dimensions ab = $a_1b_1 \gg l$ and $aa_1 = bb_1 \gg l$. The falling magnet is oriented with the north pole down, where its pole axis **p** crosses the surface at point **c**.

These current loops are identical to those of Fig.3, but arranged so that the magnet falls at point **c** outside the loop very close to aa1 or bb_1. This is shown in Fig. 5A1 and Fig. 5A2. The change in magnetic induction is only in the straight section aa_1 or bb_1 of the current loop a, a_1, b_1, b.

Results and discussion

Although the magnet falls outside the current loop, the increase in the part of the magnetic induction $\vec{B}_L$ in the section aa_1 of the loop or the increase in the part of the magnetic induction $\vec{B}_R$ in the section bb_1 of the loop cause the appearance of EMF in these sections. The magnetic induction $\vec{B}_L$ in section aa_1 creates a current directed from the sheet to us, and the magnetic induction $\vec{B}_R$ in section bb_1 creates a current directed from us to the sheet.

A circular current occurs in the counterclockwise loop in contrast to case III.3 where it is clockwise.

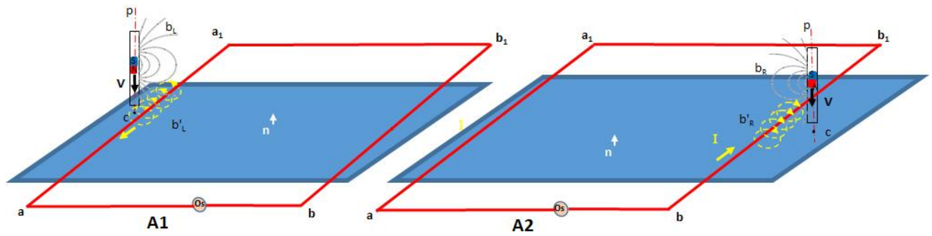


Fig.5 *A1-Increase of the magnetic induction only in section aa_1 outside the current loop*

A2-Increase of the magnetic induction only in section bb_1 outside the current loop

This current corresponds to the rammer of the generated EMF in sections aa_1 or bb_1. Here we have no change of magnetic flux in the area occupied by magnetic field lines inside the loop, which is a requirement of equation (7). We have only a partial variation of the magnetic induction in one of its sides.

6. The motionless current loop shown in Fig. 6A1 has dimensions

$ab = a_1b_1 >> l$ and $aa_1 = bb_1 >> l$.

The motionless current loop shown in Fig.6A2 has dimensions

$ab = a_1b_1 \geq l$ and $aa_1 = bb_1 \geq l$.

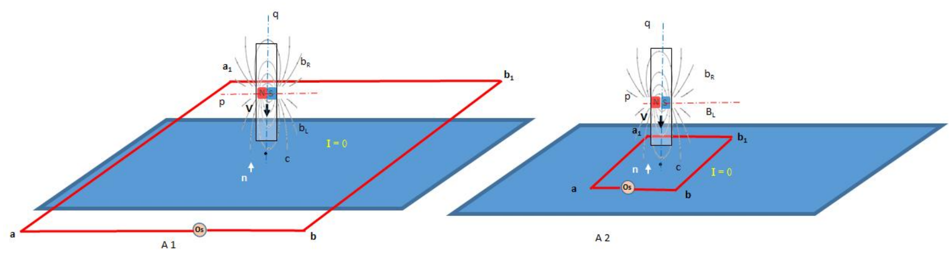


Fig. 6 *A1-Increase of $\vec{B}_L$ in current loop at $ab = a_1b_1 >> l$ and $aa_1 = bb_1 >> l$*

A2- Increase of $\vec{B}_L$ in current loop at $ab = a_1b_1 \geq l$ and $aa_1 = bb_1 \geq l$

The current loops are so arranged that the magnet falls at point **c** - the middle of the loop. Its pole axis of the falling magnet is perpendicular to the falling velocity, with the north pole to the left in the plane of the sheet. In both cases in Fig.6. we have an increase only in the magnetic

induction $\vec{B}_L$.

<u>Results and discussion</u>

In Fig.6A1, the variation of the magnetic induction $\vec{B}_L$ is too far from the wire loop and therefore no current occurs. In Fig. 6A2, the magnetic field lines cross sections aa_1 and bb_1 at the same time. The increase in the magnetic induction $\vec{B}_L$ gives rise to two equal and unidirectional currents in them, directed against each other, The resultant current is zero. At the same time, in the half-spaces relative to the dividing plane passing through the middle of the sections ab and a_1b_1, the magnetic field lines are parallel to these sections and no EMF occurs in them. The same result is obtained if we change only the magnetic induction $\vec{B}_R$.

<u>7.</u> The stationary current loops have dimensions $ab = a_1b_1 >> l$ and $aa_1 = bb_1 >> l$.

According to Fig. 7A1, the current loop is arranged so that the magnet falls at point $\mathbf{c_1}$ outside the loop, but close to section aa_1, or at point **c** - the middle of section aa_1, or at point $\mathbf{c_2}$ - inside the loop, but close to section aa_1. The pole axis of the falling magnet is perpendicular to the falling velocity, with its north pole to the left in the plane of the sheet.

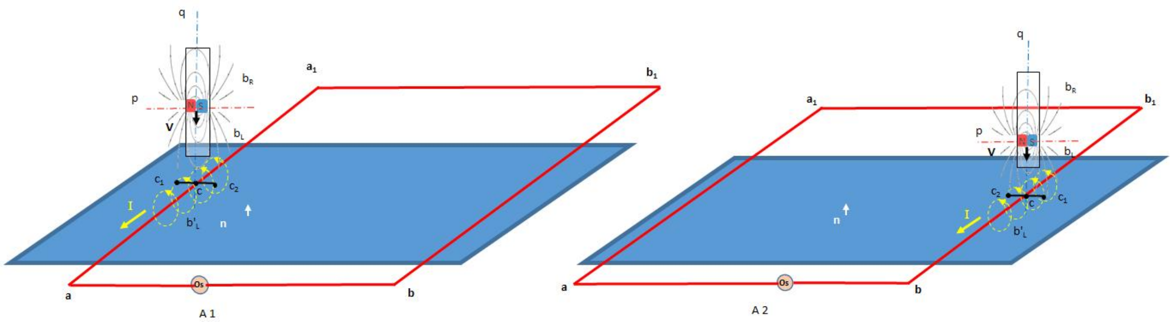


Fig. 7 *A1-Increase only of magnetic induction* $\vec{B}_L$ *in section of current loop* aa_1

A2- Increase of only the magnetic induction $\vec{B}_L$ *in a section of current loop* bb_1

According to Fig. 7A2, the current loop is arranged so that the magnet falls at point $\mathbf{c_1}$ outside the loop, but close to the section bb_1, or at point **c** - the middle of the section bb_1, or at point $\mathbf{c_2}$ - inside the loop, but close to the section bb_1.

Results and discussion

In all three drop points, the current **c**, $\mathbf{c_1}$ and $\mathbf{c_2}$ from the sections aa_1 or bb_1, the EMF arising from the increase in the magnetic induction $\vec{B}_L$ is the same and the current is in the direction from the sheet towards us. An analogous result is obtained when placing the falling magnet with the north pole to the right.

In this case, we have an increase only in the magnetic induction $\vec{B}_R$ and the generated current is in the direction from us to the sheet.

IV. Description of the experimental setup for changing the magnetic field created by a direct current in a straight wire

Into a guide plastic box in the shape of a parallelepiped fixed to a tripod is dropped from a height **h** with a velocity **V**, at the instant of fall a rectangular frame of wire, powered by a battery and having a switch **k** to turn it on and off, as shown in Fig. 8. The rectangular frame with switch **k** on falls to a movable wire loop a, a_1, b_1, b lying on a wooden table covered with shock-absorbing rubber. A USB oscilloscope is included in the wire loop. Measures are taken so that the magnetic field of the moving frame does not affect the oscilloscope. An axis **q** passes through the middle of part of the frame mm_1. The flowing current **I** in the section mm_1 creates a magnetic field, whose vector of magnetic induction is determined by the mnemonic rule of the right hand, where if the thumb is in the direction of the current, then the bent fingers determine the direction of the magnetic field[27,28,29]. This rule is accepted as technically convenient.

Note: The actual direction of the current is actually the directional movement of negatively charged electrons from the negative terminal of the voltage source to its positive terminal. Then instead of using the right hand rule, we have to use our left hand, where if its thumb points in the actual direction of the charge, then the curled fingers show the direction of the magnetic induction.

Typical cases:

1. In the case shown in Fig.8, the magnetic induction vector $\vec{B}_R$ is oriented clockwise. The magnetic field created by the current is the $\mathbf{b_R}$ magnetic field.

In Fig. 8A1 as the frame falls, axis **q** passes through point **c** lying in the middle of section bb_1 of the contour or through point $\mathbf{c_1}$ near section bb_1 inside the contour or through point $\mathbf{c_2}$ near section bb_1 outside the contour. In Fig. 8A2, when the frame falls, the axis **q** passes through the point **c** lying in the center of the contour a, a_1, b_1, b.

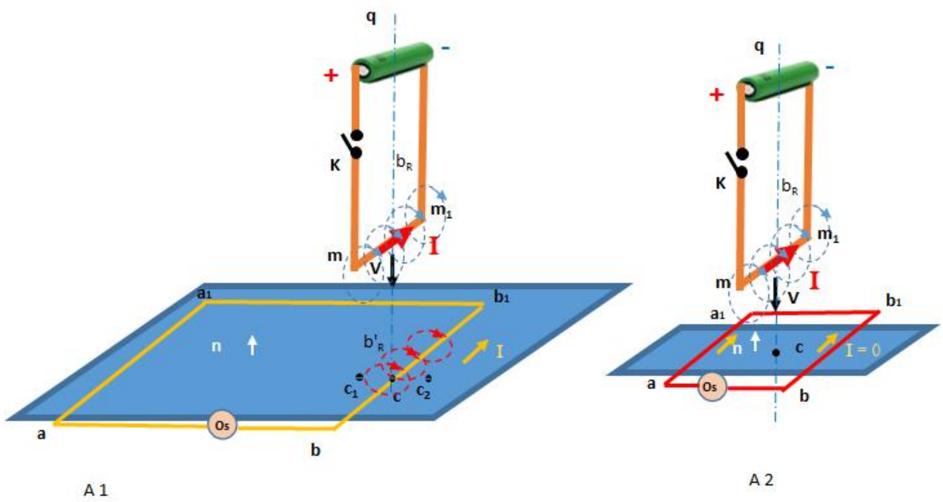


Fig. 8 *A1-Increase of magnetic induction* $\vec{B}_R$ *created by current* ***I*** *in section of current loop* bb_1

A2- Increase of the magnetic induction $\vec{B}_R$ *created by current* ***I*** *in current loop a,* a_1*,* b_1*, b*

Results and discussion

In Fig. 8A1, in all three cases, the resulting current in the wire loop is equally directed. Its direction is counterclockwise. The resulting secondary magnetic field $\mathbf{b'_R}$ is a copy of the magnetic field $\mathbf{b_R}$ that created it.

In Fig. 8A2 in the contour sections aa_1 and bb_1, the vector $\vec{B}_R$ creates currents of the same magnitude and direction, which flow against each other and compensate each other. The total current **I** in the loop is zero.

2. As the frame falls, the axis **q** passes through a point **c** lying midway between sections aa and bb of two adjacent current loops.

In the case shown in Fig.9A1, the magnetic induction vector $\vec{B}_L$ is oriented counterclockwise. The magnetic field created by the current is the $\mathbf{b_L}$ magnetic field.

In the case shown in Fig.9A2, the magnetic induction vector $\vec{B}_R$ is oriented clockwise.

The magnetic field created by the current is the $\mathbf{b_R}$ magnetic field.

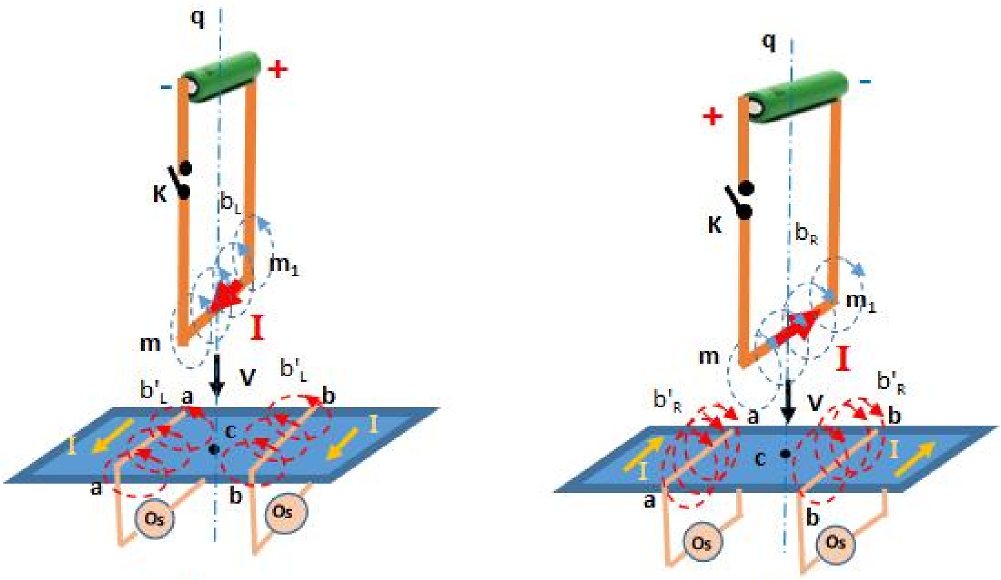


Fig. 9 *A1-Increase of magnetic induction* $\vec{B}_L$ *created by current* ***I*** *in sections aa and bb outside current loops*

A2-Increase of magnetic induction $\vec{B}_R$ *created by current* ***I*** *in sections aa and bb outside current loops*

<u>Results and discussion</u>

In Fig. 9A1, the currents **I** that arise in sections aa and bb are directed from the sheet to us, and the secondary magnetic fields $\mathbf{b'_L}$ created by them in both loops are a copy of the $\mathbf{b_L}$ magnetic field. In Fig. 9A2, the currents **I** that arise in the sections aa and bb are directed from us to the sheet, and the secondary magnetic fields $\mathbf{b'_R}$ created by them in both loops are a copy of the $\mathbf{b_R}$ magnetic field. The currents **I** flow as circular in the separate wire loops.

V. Experiments to prove the forceful characteristics of the $\mathbf{b_R}$ and $\mathbf{b_L}$ magnetic fields

<u>1.</u> In Fig. 10A1, two identical magnets are suspended freely by threads.

If the distance between them is large enough, their magnetic fields practically do not affect each other. In this position, both magnets are oriented along the Earth's magnetic field and their north poles point north.

In Fig. 10A2, two identical magnets are suspended freely on threads with opposite poles facing each other.

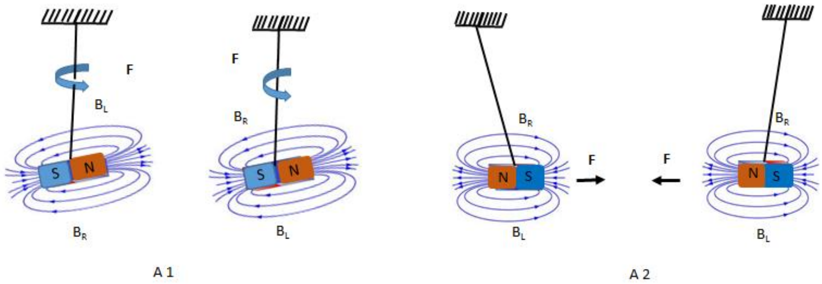


Fig. 10 *A1- Occurrence of a force of repulsion of the poles of the same name of permanent magnets and creation of a torque.*

A2 - Lack of torque when opposite poles of permanent magnets are towards each other. Attraction force appears.

Results and discussion

By shortening the distance between the magnets in Fig. 10A1, a torque occurs. They rotate counterclockwise and stably orient their oppositely named poles toward each other. As shown in Fig. 10A2 they begin to attract each other. They tend to form a single magnet with a common magnetic field.

2. In Fig. 11A1, the left frame in the section mm_1 creates a $\mathbf{b_R}$ magnetic field.

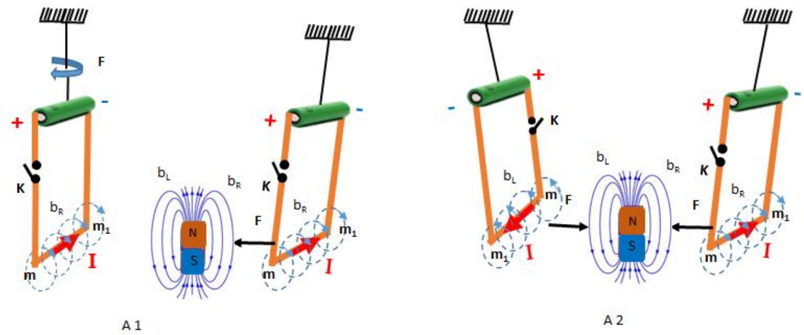


Fig. 11 *A1- Occurrence of repulsive force on* $\vec{B}_R$ *and* $\vec{B}_L$ *with torque creation. Occurrence of attraction force between* $\vec{B}_R$ *and* $\vec{B}_R$ *without torque.*

A2- Occurrence of attraction force on $\vec{B}_L$ *and* $\vec{B}_L$ *without torque. Occurrence of attraction force between* $\vec{B}_R$ *and* $\vec{B}_R$ *without torque.*

The magnetic induction $\vec{B}_L$ of the $\mathbf{b}_L$ magnetic field of the fixed magnet is opposite. At the same time, the magnetic induction $\vec{B}_R$ of the right frame in the section mm_1 is identical to the magnetic induction $\vec{B}_R$ of the $\mathbf{b_R}$ magnetic field of the stationary magnet.

In Fig. 11A2, the left frame in the section mm_1 creates a $\mathbf{b}_L$ magnetic field. The magnetic induction $\vec{B}_L$ in the $\vec{b}_L$ half-space of the fixed magnet is unidirectional. At the same time, the magnetic induction $\vec{B}_R$ of the right frame in the section mm_1 is identical to the magnetic induction $\vec{B}_R$ of the $\vec{b}_R$ half-space of the stationary magnet.

Results and discussion

In Fig. 11A1, the left free frame is rotating so that its magnetic induction to be $\vec{B}_L$ as in $\vec{b}_L$ the half-space of the stationary magnet.

At the same time, the right free frame has $\vec{B}_R$ magnetic induction and is attracting by the $\vec{b}_R$ half-space of the stationary magnet.

In Fig. 11A2, both moving frames have identical magnetic inductions with their adjacent magnetic half-spaces of the stationary magnet and are attracting by it.

3. In Fig.12A1, the left frame is freely suspended and creates a $\mathbf{b_L}$ magnetic field in the section mm_1.

The middle fixed frame creates in the section nn_1 a $\mathbf{b_R}$ magnetic field, and the right freely suspended frame in the section mm_1 creates a $\mathbf{b_L}$ magnetic field.

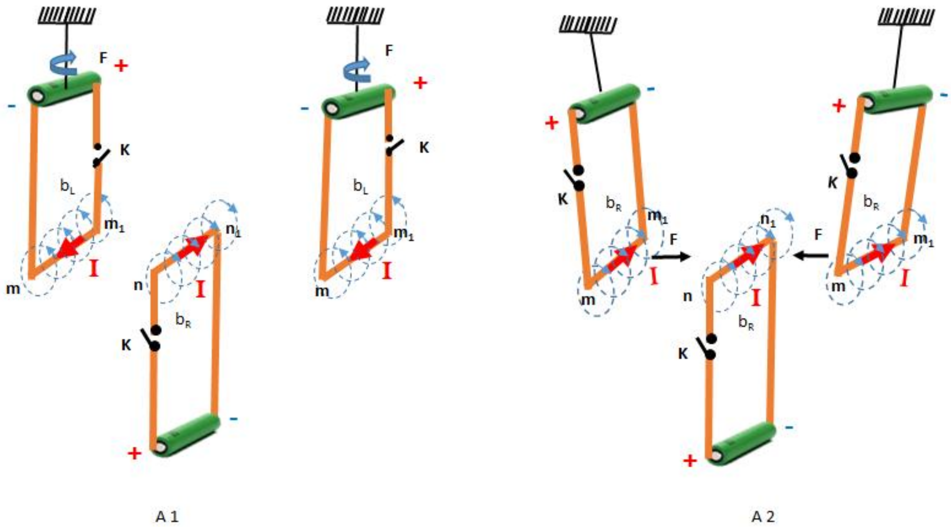


Fig. 12 *A1- Repelling the* $\mathbf{b_L}$ *fields of freely suspended current frames by the* $\mathbf{b_R}$ *field of a fixed frame and creating a torque.*

A2- Attracting the $\mathbf{b_R}$ *fields of freely suspended current frames from the* $\mathbf{b_R}$ *field of the stationary frame without torque. Occurrence of attraction force* ***F***.

In Fig. 12A2, the left freely suspended frame in section mm_1 creates a $\mathbf{b_R}$ magnetic field. The middle fixed frame creates in the section nn_1 a $\mathbf{b_R}$ magnetic field, and the right freely suspended frame in the section mm_1 also creates a $\mathbf{b_R}$ magnetic field.

Results and discussion

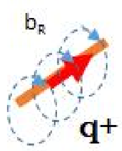
In Fig. 12A1, the freely suspended frames are rotated so that they have an identical $\mathbf{b_R}$ magnetic field to the fixed frame. When their field becomes identical in direction to the direction of the stationary frame, they mutually attract each other and form a common $\mathbf{b_R}$ magnetic field, as shown in Fig. 12A2.

VI. Poleless magnetic field. Dipole magnetic field. Differences.

The poleless magnetic field is generated by the inertial movement of charges in space and by the movement of charges in a conductor under the influence of an electric field. In the substance, external electrons can leave individual atoms and form conductive zones of free electrons or, as a result of intermolecular interactions or external forces, dissociate individual molecules, turning them into charges - positive and negative ions[30]. Radioactive decay also generates charged particles - alpha particles (positively charged helium nuclei) and beta particles - electrons[31]. Once emitted in a free state, positive and negative charges acquire linear, uniform and rectilinear motion according to Newton's first law of dynamics[32]. As long as they move undisturbed by the presence of matter and forces they can travel vast distances.

For example, the Earth is constantly exposed to the solar wind - a flow of electrons, protons and helium nuclei with speeds of up to 700 km per second[33].

A poleless magnetic field is described by magnetic lines of force in the form of concentric circles lying in a plane perpendicular to the direction of motion, which surround the charge and move along with it. The intensity of the field decreases quadratic ally as the radius of the circles increases. Looking at the direction of movement of positive charges to any point of an arbitrarily chosen line of force, we can pass a tangent vector of magnetic induction $\vec{\boldsymbol{b}}_{\boldsymbol{R}}$, which is oriented in the clockwise direction. The total magnetic induction of the poleless magnetic field of the positive charges $\overrightarrow{\boldsymbol{B_R}}$ is according to equation (4).



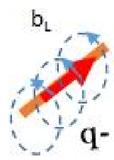


Fig. 13 *A1 - poleless* $\boldsymbol{b_R}$ *magnetic field of moving positive charges*

A2 - poleless $\boldsymbol{b_L}$ *magnetic field of moving negative charges*

Any magnetic field that is characterized only by the magnetic induction $\overrightarrow{\boldsymbol{B_R}}$ is called a $\mathbf{b_R}$ poleless magnetic field or $\mathbf{b_R}$ magnetic field.

Viewed along the direction of movement of negative charges to any point of an arbitrarily chosen line of force, we can pass a tangent vector of magnetic induction $\overrightarrow{\boldsymbol{b_L}}$, which is oriented counterclockwise. The total magnetic induction of the poleless magnetic field of the negative charges $\overrightarrow{\boldsymbol{B_L}}$ is according to equation (5). Any magnetic field that is characterized only by the magnetic induction $\overrightarrow{\boldsymbol{B_L}}$ is called a $\mathbf{b_L}$ poleless magnetic field or $\mathbf{b_L}$ magnetic field. Fig. 13 shows the two types of poleless magnetic fields.

Moving charges in a dipole magnetic field are acted upon by the Lorentz force:

$$\vec{\boldsymbol{F}} = q\vec{\boldsymbol{E}} + q\vec{\boldsymbol{V}} \times \vec{\boldsymbol{B}} \qquad \textbf{(15)}$$

where $\vec{\boldsymbol{V}}$ is the velocity, **q** the charge of the particle, $\vec{\boldsymbol{E}}$ is the electric field intensity, and $\vec{\boldsymbol{B}}$ the magnetic induction of the field, since moving positively charged particles are surrounded by $\mathbf{b_R}$ poleless magnetic field and negatively charged particles from are surrounded by $\mathbf{b_L}$ poleless magnetic field.

Any current by definition is the amount of charge **q** passed per unit time **t**. Therefore, any magnetic field around a single conductor carrying an electric current is a pole less magnetic field. It is composed of only one type of magnetic field lines in the form of concentric circles without beginning and without end around the wire.

The actual movement of electrons in wires under the influence of an electric field is from the minus end of the source to its plus end. Therefore, looking in the direction of electron motion, the magnetic induction created by the current is $\overrightarrow{\boldsymbol{B_L}}$.

The magnetic field around each individual current-carrying wire is $\mathbf{b_L}$ a poleless magnetic field. The wires used to make electromagnets have an electronic conductivity of 10^4 to 10^6 $\Omega^{-1}.cm^{-3}$. According to the zone model of the solid, if **N** is the number of atoms making up the solid, the overlapping of their **N** atomic orbitals at a certain level (1s, 2s, . . .) allows **N** "molecular" orbitals to be obtained [34]. The number of N in 1 moll is equal to $6.02.10^{23}$ - Avogadro's number. Due to the proximity of the levels forming the zone, it can be assumed that the energy of the electrons can be varied in a quasi-continuous manner. Conduction exists only if an applied electric field or external force causes at least some of the electrons to make a transition to an energy level higher than the one they are at.

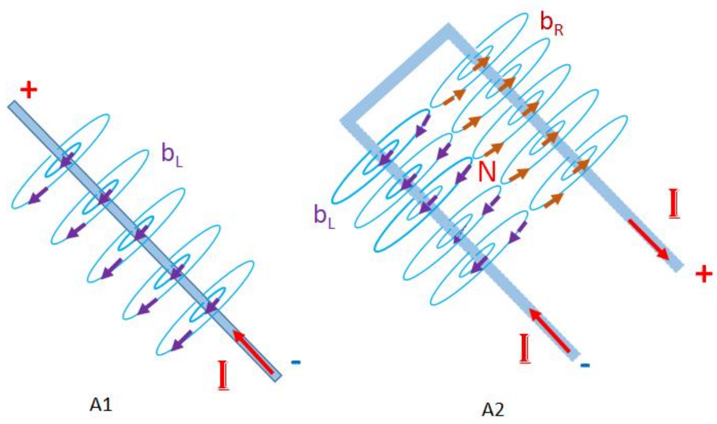


Fig. 14 *A1 - poleless* $\boldsymbol{b_L}$ *magnetic field of moving negative charges.*

A2 – Obtaining a dipole magnetic field from a $\boldsymbol{b_L}$ *poleless magnetic field by bending the wire.*

Conductors [35] are a way of setting a desired path for the movement of electrons in space. They cause the electrons under the influence of an applied electric field to move forcibly along a predetermined trajectory in the form of a solenoid, a straight wire, a toroid, etc. In the case of deionization, the electrons generate a $\mathbf{b_L}$ poleless magnetic field in the form of concentric circles around the wire with a quadratic decrease in its intensity as the radius of the circles increases, as shown in Fig. 14A1.

If we bend the wire, as it is done for example in Fig. 14A2, then in the right section of the wire the electrons are forced to move in the opposite direction compared to the left section. If the distance between the left and right sections of the bent wire is small enough, we perceive the general magnetic field of the wire as a dipole. At the same time, the north pole is towards us. Although the electrons generate a magnetic field $\mathbf{b_L}$ all the time, relative to an observer, only in the left section of the wire is the magnetic field is $\mathbf{b_L}$, and in the right section of the wire the magnetic field is $\mathbf{b_R}$.

The magnetic field created by the flow of current in the bent wire is dipole. It generates EMF in an independent wire loop according to Faraday's law. If the distance between the left and right sections of the bent wire is so great that the magnetic fields of the individual sections do not affect each other, then in both sections we have a poleless magnetic field. In this case, although both magnetic fields are $\mathbf{b_L}$, they are in opposite directions, and therefore to an observer looking at the plane of the sheet the magnetic field appears as $\mathbf{b_R}$ in the right part. In fact, precisely because the two $\mathbf{b_L}$ fields are with opposite directions , they generate opposite EMFs and have opposite force actions.

And with permanent magnets, things are similar. In them, the generators of the magnetic field are the equally oriented spin orbital motions of the electrons of many of the atoms. The more the spin orbital motions of the electrons are unidirectional, the stronger the magnetic field. The velocity of an electron [36,37] traveling in the first Bohr orbit [38] is given by the equation

Vrel = Z /137, where **Z** is the atomic number of the element under consideration and 137 is the speed of light in atomic units, also known as the fine structure constant [39]. For example for Z =26 for the iron, we get that in its atom having a radius of 156 pm the average orbital speed of the electrons is about 5.7 x 10^7 m/s. The average time for one of its electrons to make half a circle is π x156 x10^{-12} ≈ 4.9x10^{-14} s. In other words, the vector of magnetic induction $\vec{B}_L$ generated by it turns 180 degrees in ≈ 4.9 femtoseconds in the eternal spin orbital motion of electrons. The magnetic field created in the two opposite directions from the magnetic inductions $\vec{B}_L$ behaves as a stationary dipole magnetic field.

Each permanent magnet or electromagnet according to Fig.1 creates a dipole magnetic field with a total magnetic induction $\vec{B}$. The space around the magnet relative to any of the j number of its pole planes according to (3) and (6) consists of $\vec{b}_R$ and $\vec{b}_L$ half-spaces. The magnetic induction $\vec{B}$ of each magnetic pole is a vector sum of the magnetic induction $\vec{B}_R$ and the magnetic induction $\vec{B}_L$ according to (6). Therefore, the search for the magnetic monopole as a separate magnetic pole (north or south) of the magnetic field in order to create a unified field theory is meaningless. As best seen in Fig.10A2 opposite poles of magnets attract because the $\mathbf{b_R}$ field of one magnet is opposite the $\mathbf{b_R}$ field of the other magnet and at the same time the $\mathbf{b_L}$ field of the same magnet is opposite the $\mathbf{b_L}$ field of the other magnet. Unidirectional magnetic fields are attract and opposite repel to create a torque to form a unidirectional magnetic field.

Now is the time to note that this is the significant difference from the electric field, where unlike charges attract and like charges repel.

We proved with the experiments from IV.1 to IV.7 that the fields $\mathbf{b_R}$ and $\mathbf{b_L}$, when their magnetic inductions change, generate in any section of a wire loop opposite in sign EMF. We also proved with experiments V.1 to V.3 that the two magnetic fields $\mathbf{b_R}$ and $\mathbf{b_L}$ have opposite force actions.

From the experiments made according to Fig.15, it was found that the positive α particles emitted by the radioactive Radium are deflected to the left (to the $\vec{b}_R$ magnetic half-space) in a dipole magnetic field, and the negative β particles are deflected to the right (to the $\vec{b}_L$ magnetic half-space)[40].

This experiment is proof that moving positive charges generate a $\mathbf{b_R}$ magnetic field and moving negative charges generate a $\mathbf{b_L}$ magnetic field because above we proved by experiments that unidirectional magnetic fields attract.

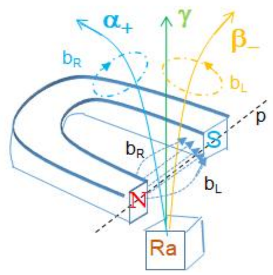


Fig. 15 *In radioactive decay of Radium, the positively charged α+ particles surrounded by a $\boldsymbol{b_R}$ magnetic field are deflected to the left towards the $\vec{b}_R$ half-space of the magnet, and the negatively charged β-particles surrounded by a $\boldsymbol{b_L}$ magnetic field are deflected to the right towards the $\vec{b}_L$ half-space of the magnet.*

The magnetic field of any permanent magnet is created by the uniformly oriented spin orbital motions of the electrons in its constituent substance.

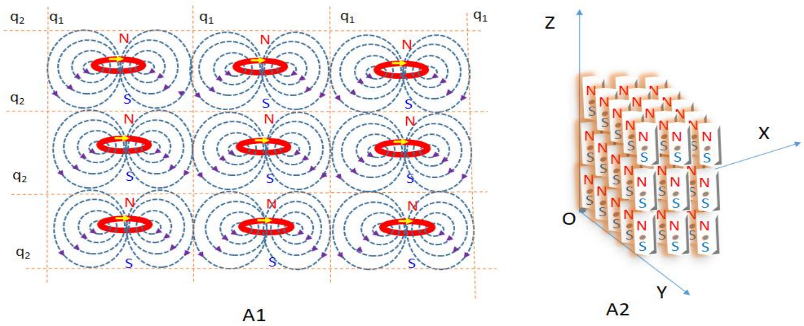


Fig. 16 *A1 – Equally oriented spin orbital motions of electrons in a permanent magnet*

A2 – Visual representation of a structure of a permanent magnet

As can be seen from Fig. 16 A1 regions with equally oriented spin orbital motions are separated by multiple $\mathbf{q_1}$ planes that are parallel to the pole plane, where the magnetic fields on both sides of the planes are oppositely directed.

If we cut a permanent magnet along such a plane, the resulting two parts repel each other. However, if we cut the magnet along one of the planes $\mathbf{q_2}$, which are perpendicular to the pole plane, the resulting two parts attract each other because the magnetic fields of the half-spaces of both halves are unidirectional41. In Fig. 16 A2 shows a visual representation of the structure of a permanent magnet according to the findings made when examining Fig. 16 A1.

VII. Conclusion

Permanent magnets and electromagnets have two poles. Those of the same name create a torque by repelling each other, and those of the same name do not create a torque, but only attract each other. The magnets generate a dipole magnetic field around them, which, relative to any polar plane, consists of two equal-module and opposite-direction $\mathbf{b_R}$ and $\mathbf{b_L}$ parts. The magnetic field $\mathbf{b_R}$ is characterized by magnetic lines of force without beginning and end, oriented clockwise. The magnetic field $\mathbf{b_L}$ is characterized by magnetic lines of force without beginning and end, oriented counterclockwise. Permanent magnets and electromagnets composed of wire coils always and simultaneously have two poles and contain the magnetic fields $\mathbf{b_R}$ and $\mathbf{b_L}$. In this sense, the search for a magnetic monopoly, i.e. a magnet with only one pole is pointless.

However, there is a poleless magnetic field that surrounds any moving charge with magnetic field lines in the form of concentric circles. The latter lie in planes perpendicular to the direction of charge movement. Their magnetic induction decreases quadratic ally as the radius of the circles increases. The poleless magnetic field is actually the primary and most elementary magnetic field.

Viewed in the direction of motion of the positive charges, the magnetic field around them is only $\mathbf{b_R}$ magnetic field. Viewed in the direction of motion of the negative charges, the magnetic field around them is only $\mathbf{b_L}$ magnetic field.

Typical pole less magnetic fields are those generated by linear inertial motion of charges such as streams of helium nuclei, protons and electrons.

Under the influence of central forces or forced movement along certain circular trajectories, the magnetic field can be considered as dipole or poleless depending on the ratio of the size of the radius of the orbital movement of the charges and the size of the radius of the most distant magnetic lines of force.

In matter, the movement of free charges has radii significantly smaller than the radii of the magnetic field lines. That is why the time for the reversal of the direction of motion of the charges during their orbit is extremely small and the effect of the magnetic field on any objects is dipole. Therefore, the effects of both $\mathbf{b_R}$ and $\mathbf{b_L}$ magnetic fields must be considered simultaneously.

In electromagnets made of wire coils, we have a forced movement of negative charges along the trajectories created for them by the coils.

In practice, in most electromagnets the radii of the coils are smaller than the radii of the magnetic field lines and the field created is a dipole.

When the radii of the coils are significantly larger than the radii of the magnetic field lines, the magnetic field is practically poleless in every section of the wire loop. There is a $\mathbf{b_L}$ magnetic field on one side of each pole plane and a $\mathbf{b_R}$ magnetic field on the other side.

In the dipole magnetic field, the created magnetic inductions $\vec{\boldsymbol{B}}_{\boldsymbol{R}}$ and $\vec{\boldsymbol{B}}_{\boldsymbol{L}}$ form a total magnetic induction $\vec{\boldsymbol{B}}$, according to equation (6). In the poleless magnetic field, the magnetic induction $\vec{\boldsymbol{B}}_{\boldsymbol{R}}$ or $\vec{\boldsymbol{B}}_{\boldsymbol{L}}$ created is actually the total magnetic induction $\vec{\boldsymbol{B}}$. At the same time, both the dipole magnetic field and the poleless magnetic field satisfy Maxwell's equations and Lorentz's law.

Therefore, it holds:

$$\mathrm{Div}(\vec{\boldsymbol{B}}_{\boldsymbol{R}} + \vec{\boldsymbol{B}}_{\boldsymbol{L}}) = 0 \qquad \textbf{(16)}$$

$$\mathrm{Rot}\,\vec{\boldsymbol{E}} = \frac{\partial}{\partial t}(\vec{\boldsymbol{B}}_{\boldsymbol{R}} + \vec{\boldsymbol{B}}_{\boldsymbol{L}}) \qquad \textbf{(17)}$$

$$\mathrm{Rot}\,(\vec{\boldsymbol{B}}_{\boldsymbol{R}} + \vec{\boldsymbol{B}}_{\boldsymbol{L}}) = \frac{j}{\mathcal{E}_0 c^2} + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}\,, \qquad \textbf{(18)}$$

$$\vec{\boldsymbol{F}} = \mathbf{q}\vec{\boldsymbol{E}} + \mathbf{q}\vec{\boldsymbol{V}} \times (\vec{\boldsymbol{B}}_{\boldsymbol{R}} + \vec{\boldsymbol{B}}_{\boldsymbol{L}}) \qquad \textbf{(19)}$$

The way to create a unified field theory goes through the poleless magnetic field.

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