Rotating Dipole Effect -- A New Theory For The Origin Of The Earth's Magnetic Field

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How the earth(and also stars and other planets) produces its magnetic field is a long-standing puzzle. Many theories has been proposed for the explanation of the earth's magnetic field. The current believe is that earth's magnetic field is generated by "dynamo effect". Since 1999, "dynamo effect" sodium experiments has been able to spontaneously produced magnetic field[1-2]. But "dynamo theory" is very complex, after so many years of research, a working model "remains elusive"[3]. Here I proposed that the magnetic field of the earth is caused by "rotating dipole effect" -- In a rotating material, only those electrons with the magnetic dipole moments that are parallel to the axis of rotation can avoid changing direction relative to the galaxy and relative to the surrounding electrons or atoms at the same time, thus more electron's magnetic dipole moments are pointing to the direction parallel to the axis of rotation. If the material is paramagnetic, then measurable magnetic field may be created. This new theory is consistent with all the observed phenomena and can make prediction of what material can produced magnetic field and what material can not.

In 1600, William Gilbert proposed that the whole earth is a huge magnet[4]. Initially it was thought that the earth's magnetism was of ferromagnetic origin. But later it was found that the ferromagnetic substance does not retain magnetism when heated above the Curie point, and it is believed that the temperature inside the earth is higher than the Curie point of any known ferromagnetic substance. So this theory had to be rejected.

In 1947, P.M. Blackett[5] proposed that a rotating body should generate magnetic field proportional to its angular momentum. But in 1952, he reported an experiment with negative result for this theory[6].

"Dynamo theory", first suggested by Joseph Larmor in 1919[7], is now believed to be the origin of the earth's magnetic field. In this dynamo mechanism, fluid motion in the Earth's outer core moves conducting material across an already existing, weak magnetic field and generates an electric current. The electric current also produces magnetic field, so the total magnetic field is growing. Finally the growth is balanced by ohmic decay.

Efforts must be made to achieve a working model for the "dynamo theory", at the same time we should also open to other theories too, especially if the theory is consistent with all the observed phenomena.

To elaborate the "rotating dipole effect", lets consider an electron inside a rotating cylinder of paramagnetic material(paramagnetic material is non-ferromagnetic material which will create magnetic field with direction same with the externally applied magnetic field. The magnetic field is created by electron's magnetic dipole moments in the material[8]). The cylinder is rotating one revolution per second(1 rev/sec). The magnetic dipole moment(hereafter simply "magnetic moment") of the electron is pointing to the side of the cylinder(rectangular to the axis of rotation of the cylinder)(Figure 1a).

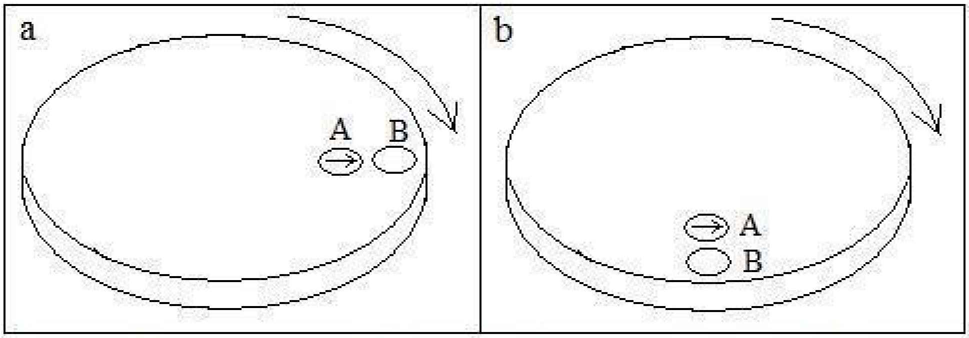

Fig. 1. a) Magnetic moment of electron A is pointing to the side of the cylinder and also to electron B. b) One quarter of a second later, the direction of magnetic moment A was unchanged relative to the galaxy, but its direction was changed relative to electron B.

In Figure 1a, magnetic moment of electron A is pointing to the side of the cylinder and also to electron B. One quarter of a second later(Figure 1b), the direction of the magnetic moment A was unchanged relative to the galaxy(or the earth), but its direction was changed relative to the other atoms or electrons, including electron B. In classical view, magnetic moment that changing direction relative to the other charges is unstable(direction unstable, or direction have a tendency to change), because any charges will be influenced by the changing magnetic field(Faraday's Law states that a changing magnetic field creates an electric field, which will move the charges), this means that the charges will influence the magnetic moment(electron A) too. So we can conclude that electron with magnetic moment pointing to the side of the cylinder, and always changing direction relative to the surrounding atoms or electrons, is unstable.

Now lets consider a situation where the direction of the electron's magnetic moment is unchanged relative to the surrounding atoms or electrons.

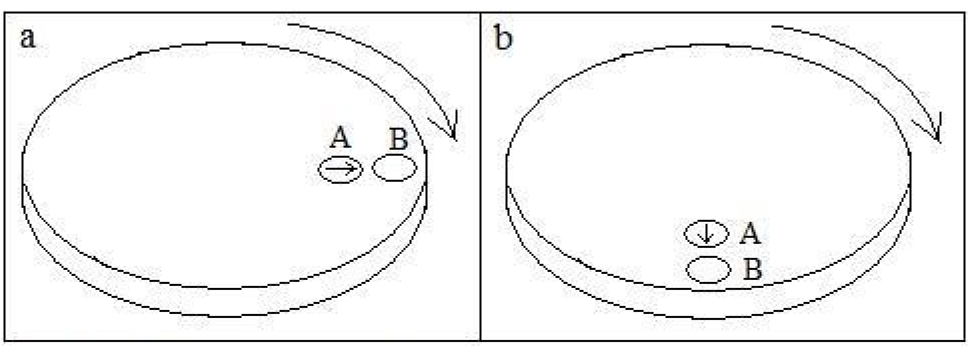

Fig. 2. a) Magnetic moment of electron A is pointing to the side of the cylinder and also to electron B. b) One quarter of a second later, the direction of magnetic moment A was unchanged relative to electron B, but its direction was changed relative to the galaxy.

In Figure 2a, magnetic moment of electron A is pointing to the side of the cylinder and also to electron B. One quarter of a second later(Figure 2b), magnetic moment A was unchanged relative to electron B and surrounding atoms, but its direction was changed relative to the galaxy. Magnetic moment of electron that constantly changing direction relative to the galaxy is unstable, because there is angular momentum associated with the magnetic moment of an electron[9], this means that the electron's angular momentum is constantly changing direction. Equation for the torque of changing angular momentum is[10] :

$$\tau = dL / dt \qquad (1)$$

where L is angular momentum and t is time. Constantly changing angular momentum means that some external torque must be constantly acting on the angular momentum.

We can conclude here that those magnetic moments of electrons that pointing to the side of the cylinder are unstable, because it is impossible for the magnetic moment's direction to keep unchanged relative to the surrounding atoms or electrons, and at the same time unchanged relative to the galaxy.

Now consider an electron with magnetic moment that pointing to the top of the cylinder(parallel to the axis of rotation).

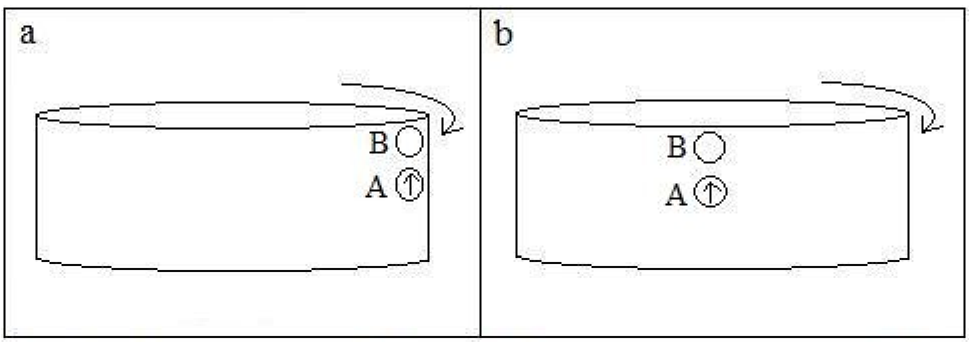

Fig. 3. a) Magnetic moment of electron A is pointing to the top of the cylinder and also to electron B. b) One quarter of a second later, the direction of magnetic moment A was unchanged relative to electron B, and also unchanged relative to the galaxy.

In Figure 3a, magnetic moment of electron A is pointing to the top of the cylinder and also to electron B. One quarter of a second later(Figure 3b), the direction of magnetic moment A is unchanged relative to the galaxy, and its direction also unchanged relative to the surrounding atoms or electrons, including electron B. So we can conclude that magnetic moments of electrons whose direction are pointing to the top of the rotating cylinder is more stable. This is also true for magnetic moments that pointing to the bottom of the cylinder.

Because electrons with magnetic moment that pointing to the top or bottom of the rotating cylinder are more stable, they tends to remain in that direction for a longer time. So more magnetic moments are pointing to the top and bottom direction than to the other directions. Because of the randomize behavior, sometimes there are more magnetic moments that pointing to one direction(top or bottom) than to the other opposite direction. This imbalance will create a small "seed" magnetic field. This "seed" magnetic field may also comes from the external magnetic field, for example earth's magnetic field.

In the presence of magnetic field, the paramagnetic material will be magnetized follow the equation[11] :

$$\mathbf{M} = \chi \mathbf{H} \quad (2)$$

where M is magnetization, χ is magnetic susceptibility and H is magnetizing field. For paramagnetic material, magnetic susceptibility is positive, while magnetic susceptibility for diamagnetic(diamagnetic material is the material that creates a weak magnetic field in opposite direction to an externally applied magnetic field. The weak magnetic field is created by electron's magnetic moments in the material[8]) material is negative. Equation 2 shows that magnetization will be increased proportional to the magnetizing field.

So for paramagnetic material, the "seed" field will attract more magnetic moments to its direction, and the magnetic field is started to "grow". If the material is not rotating and without external magnetic field, then the alignment of the magnetic moments will be destroyed by thermal agitation. But because the material is fast-rotating, the magnetic moments attracted to that direction(top or bottom) will remained in that direction for longer time because it is more stable in that direction. So the bigger magnetic field can attract even more magnetic moments to its direction. Finally, this will be balanced by the thermal agitation that caused some of the electrons to became randomly oriented. So the magnetic susceptibility of a material may changed when rotating, and a rotating non-diamagnetic material may be able to spontaneously produce measurable magnetic field.

To be able to spontaneously produce magnetic field, there is a condition, the size of the rotating material must be big enough. If the material is too small, the "seed" field created by the imbalance will be too small to attract more magnetic moments to its direction, so this "seed" field will be immediately "destroyed" by the thermal agitation. Another condition is that the speed of the rotation must be fast enough. A faster rotation will make the magnetic moments of electrons that points to the top or bottom of the cylinder relatively more stable.

If the rotating material is diamagnetic material and no external magnetic field present, then no macroscopic measurable magnetic field should be created. Because any "seed" magnetic field created in the rotating material will be opposed by opposite magnetic field created by diamagnetic effect.

The above theory can be used to explain the origin of the earth's magnetic field and the results of the "dynamo effect" sodium experiments. According to "rotating dipole effect", the magnetic field of the earth and also the magnetic field detected in the "dynamo effect" experiments is created by the alignment of the electron's magnetic moments, not by electric current.

This theory is consistent with all the observed phenomena. The material that can spontaneously produced magnetic field in the "dynamo effect" experiments, sodium, is paramagnetic material[12]. The material inside the earth is believed to be paramagnetic[13]. The direction of magnetic field created is in agreement with this theory. The rotation of the earth is slow, but this is balance out by the gigantic size of the earth.

To confirm this theory, a few experiments are suggested here :

1) Rotate paramagnetic and other materials and check whether the magnetic susceptibility for a material will changed under fast-rotation(experiment to check whether the magnetic susceptibility for liquid metal will change when rotating has been done, accidentally by

"dynamo effect" experiments, and "dynamo theorist" interpreted the magnetic field created as produced by electric current, not by increment of magnetic susceptibility).

2) Rotate solid paramagnetic materials with sufficient size. Since "dynamo effect" can not take place inside a solid object[14], if magnetic field is produced by the solid paramagnetic materials, this will give a "solid" confirmation for this theory.

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