Gyrocompass Effect And The Origin Of The Earth's Magnetic Field

Low Yuen Wang (Malaysia)

How the earth produces its magnetic field is a long-standing puzzle. Many theories have been proposed for the explanation of the earth's magnetic field. In 1600, William Gilbert proposed that the whole earth is a huge magnet[1]. But this theory had to be rejected because permanent magnet lost its magnetism at high temperature inside the earth. In 1919, Joseph Larmor suggested "Dynamo Theory"[2]. In this theory, the earth's magnetic field is produce by electric current. Although this theory is promising, but a working model "remains elusive"[3]. Here I propose that the magnetic field of the earth is produced by the alignment of electrons. Because the earth is rotating, only electron spins that pointing to the north-south direction can maintain their direction relative to the galaxy and relative to other electrons and atoms, so electrons have a tendency to point to north-south direction. This theory/effect is proved by a commercial tool called gyrocompass.

To elaborate the 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 similar with the externally applied magnetic field. The magnetic field is created by electron's magnetic moments in the material). The cylinder is rotating one revolution per second(1 rev/sec). The magnetic moment of the electron is pointing to the side of the cylinder(rectangular to the axis of rotation of the cylinder)(Figure 1a).

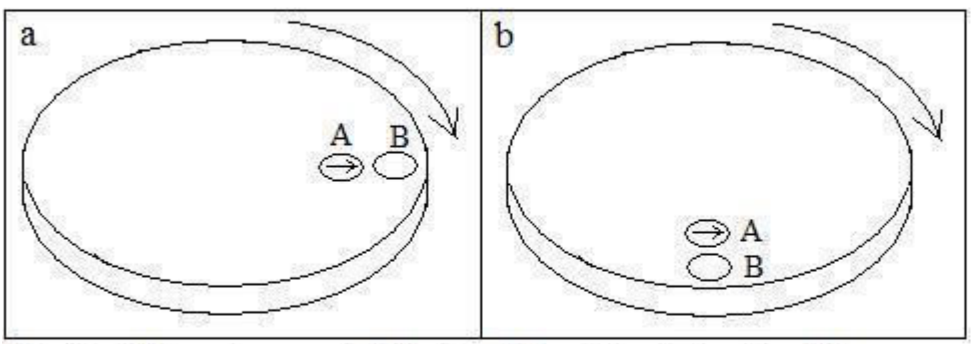

Fig. 1. a) Magnetic moment of electron A is pointing to the side of the cylinder and also to electron B. b) One quarter of a second later, the direction of magnetic moment A was unchanged relative to the galaxy, but its direction was changed relative to electron B.

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. 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.

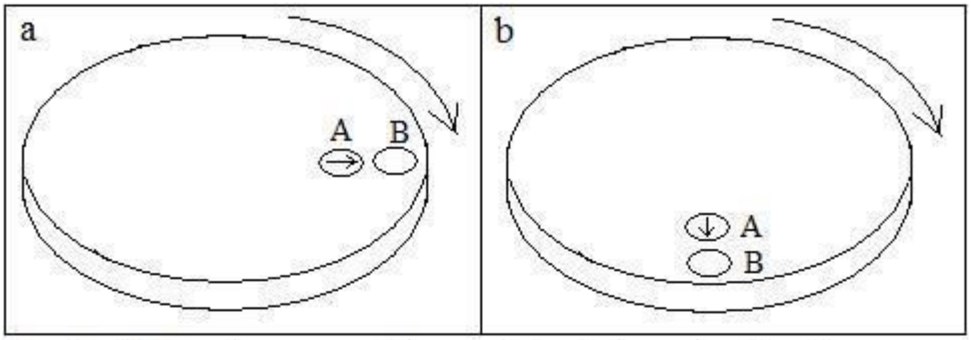

Fig. 2. a) Magnetic moment of electron A is pointing to the side of the cylinder and also to electron B. b) One quarter of a second later, the direction of magnetic moment A was unchanged relative to electron B, but its direction was changed relative to the galaxy.

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 or electrons, 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, this means that the electron's angular momentum is constantly changing direction. Equation for the torque of changing angular momentum is[4] :

$$\boldsymbol{\tau} = \mathbf{dL / dt} \qquad (1)$$

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).

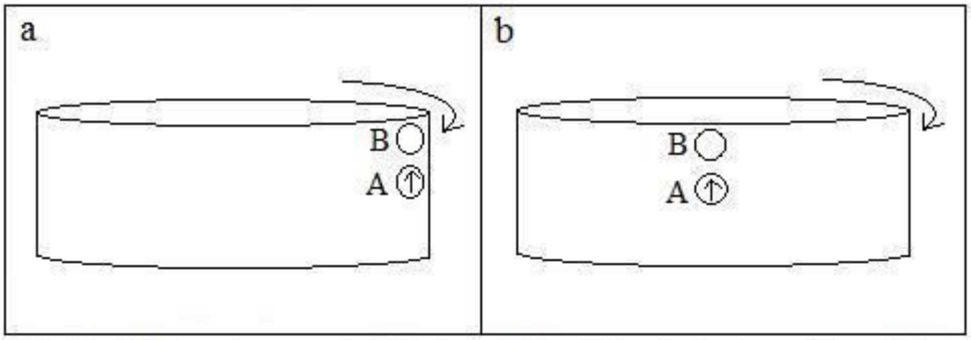

Fig. 3. a) Magnetic moment of electron A is pointing to the top of the cylinder and also to electron B. b) One quarter of a second later, the direction of magnetic moment A was unchanged relative to electron B, and also unchanged relative to the galaxy.

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 are 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 or galactic magnetic field.

In the presence of magnetic field, the paramagnetic material will be magnetized follow the equation[5] :

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

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) 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 will start 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 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.

To prove this effect, we can use the angular momentum of a rotating disc to replace the angular momentum of an electron, so that we can see the changing direction of an angular momentum. We can rotate a disc in which the axle is able to change direction. The disc is hosted by a tool which is also rotating by itself. If we do this experiment, we should be able to see that the disc will precess and finally aligned with the rotating tool. But before we really do this experiment, we should find out whether such experiment has been done before. Surprisingly, a similar "experiment" has been done more than one hundred years ago! It is a tool called gyrocompass.

Gyrocompass is a tool widely used on ships to find true north. It used an electrically powered, fast-rotating gyroscope. If a rotating gyroscope can freely change direction without much friction, because of the conservation of angular momentum, it will always points to a fix point in outer space. Since the earth is rotating, in the eyes of an observer on earth, that gyroscope's axis will complete a full rotation once every 24 hours. But if there are frictions when the gyroscope is changing direction, then the gyroscope will precess and align with the earth's axis. This is due to the fact that when the gyroscope is pointing to east or west, it will either changing direction relative to a fix point in outer space, or it will be changing direction relative to the earth. Only when the gyrocompass is pointing to the true north, it can point to a fix point in outer space without changing direction relative to the earth.

Since gyrocompass is an "experimental" proof for the effect, this effect is named "Gyrocompass Effect" here.

"Gyrocompass Effect" not only can be used to explain the origin of earth's magnetic field, it also has the potential to explain some other natural phenomena or experimental results, for example the magnetic field of cosmic-dust, other planets and stars, Barnett Effect and "Dynamo Effect" experimental results.

Using "Gyrocompass Effect", it is easy to come into conclusion that convection is not necessary for producing magnetic field, and, in fact, have a negative effect to the production of magnetic field. So far, successful "Dynamo Effect" experiments are not convective.

In "Dynamo Effect" experiments, the material that can spontaneously produced magnetic field in the experiment, sodium, is paramagnetic material[6], this is consistent with "Gyrocompass Effect".

"Dynamo Effect" experiment is still an active field of research. Experiments should be done to find out whether the magnetic field produced in the experiments are produced by "Dynamo Effect" or "Gyrocompass Effect".

References

1. Choudhuri, A. R. *The Physics of Fluids and Plasmas: An Introduction for Astrophysicists,* 340(Cambridge University Press, Cambridge, 1998).

2. Larmor, J. How could a rotating body such as the sun become a magnet? *Report of the British Association for the Advancement of Science*, 159-160(1919).

3. Gubbins, D. & Herrero-Bervera, E. *Encyclopedia of Geomagnetism and Paleomagnetism*, 315

(Springer, Berlin, 2007).

4. Frautschi, S. C. & Olenick, R. P. & Apostol, T. M. & Goodstein, D. L. *The Mechanical Universe : mechanics and heat*, 337(Cambridge University Press, Cambridge, 2008).

5. Knoepfel, H. *Magnetic Fields: Theory and Applications,* 7(Wiley-IEEE, New York, 2000).

6. Blakemore, J. S. *Solid State Physics,* 434(Cambridge University Press, Cambridge, 1985).