Magnetic dipole

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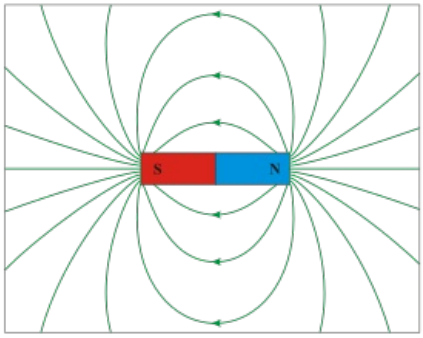
SOMEWHAT LONG - HOWEVER WELL WRITTEN, NOT MUCH REPETITION

Introduction



Schematic representation of a magnetic dipole

A dipole is an idealized system that is used for an approximate description of a field created by more complex systems of charges. There are three main types of dipoles, which are electric, magnetic and current dipoles. Magnetic dipole is an analogue of an electric dipole which can be represented as a system of two «magnetic charges». In fact, this analogy is debatable, as from the perspective of modern electrodynamics, magnetic charges (or magnetic monopoles) do not exist. Nonetheless, a basic magnetic dipole can be refferred to as a tiny magnet composed of adjacent positive and negative charges. Considering that a closed circuit is believed to be the original source of magnetism, a typical example of a magnetic dipole would be a wire loop with constant current passing through it. In this connection, magnetic dipole also serves as a source of stationary magnetic field, similar to how an electric charge is serves the function of a source of the electrostatic field.

Definition

Magnetic dipole moment, or simply magnetic moment is a vector quantity and the main value that is used to characterize magnetic properties of some matter. The best way to define it would be to think of a maximum amount of torque that can be caused by magnetic force on a dipole arising per unit value of surrounding magnetic field in vacuum. According to right-hand rule, the magnetic dipole moment points through the loop. The magnitude is current in the loop times the area of the loop. The unit for measuring magnetic dipole moment is not a base unit in the International System of Units (SI), so it is measured in $A*m^2$ or J/T. Elementary particles, atomic nuclei, as well as electric shells of atoms and molecules all have some magnetic moment. In elementary particles, according to quantum mechanics, the dipole moment is caused by their own mechanical moment, which is called spin.

A formula that would allow to measure magnetic dipole moment of an electron is given by:

$$M = G(-eL/2m)$$

Where,

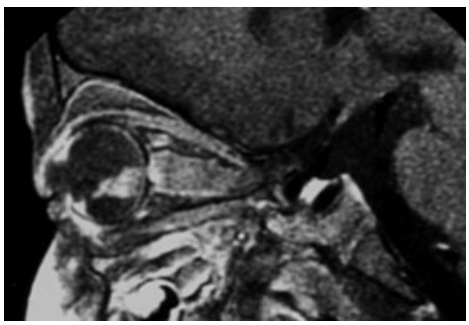
e = charge of electron,

m = mass of electron at rest

L = angular momentum of the electron

G = correlation factor.

Importance in clinical medicine



Detection of retinoblastoma using MRI

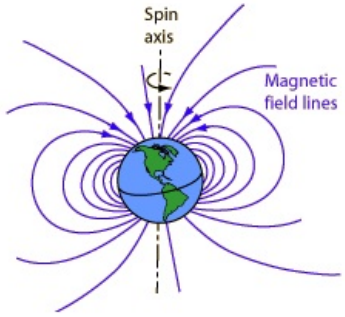
Due to the fact that the phenomenon of a magnetic dipole is directly connected with magnets that are commonly used in medicine, the concept of a magnetic dipole is widely present in many medical spheres. One of the most important scientific breakthroughs in the field of medical use of magnets that changed the course of history was the invention of nuclear magnetic resonance spectroscopy (NMR-spectroscopy). Understanding of a basic dipole-dipole principle, when two nuclei that have a magnetic moment can interact with each other even being separated by some space, as well as an ability to calculate the vector of this dipole-dipole interaction, resulted in an appearance of a brand-new way of structural medical examination of compounds in the late 1940s'. With the development of NMR-spectroscopy over the years, it became one of the dominant ways of determining structure of proteins, as well as studying dynamics of biomolecules, and even creation of biologically active substances, which emphasizes it's importance in the sphere of medical pharmacology.

In addition, the study of NMR tomography is widely used in magnetic resonance imaging (MRI), as an essential part of it is analyzing the NMR of protons and nuclei of hydrogen, which are present in almost every tissue in a human body. MRI tomography allows for qualitative and non-invasive visualization of brain, spinal cord and other internal organs.

The power of magnetic dipole interaction is also applied in altermative medicine, for instance, in magnotherapy. Some practitioners state that body tissues, when being exposed to a magnetic field with a steady current (magnetostatic field), are capable of changing physicochemical properties of aqueous systems, as well as changing orientation of big ionized biological molecules (such as enzymes), which leads to acceleration of biochemical and biophysical processes in our body. However, the methodology used in magnetic therapy is being strongly criticized by various institutons, including the American National Science Foundation (NSF), which questions rationality and effectiveness of this type of medical practice.

Impact on the environment

One of the generalized examples of a magnetic dipole is Earth with its north and south poles. It has been noted that the change in level of constant magnetic field can affect living creatures. Even though life on Earth existed in different magnetic field conditions, there is a popular belief that biological systems managed to adapt to this constantly changing environmental feature. Interestingly, our planet switches orientation of its magnetic field approximately every 200 thousand years, and this shift keeps on going for 4-5 thousand years. One of the most interesting hypotheses suggests that occurence of homochirality (property of distinguished mirror image) in biology is directly linked to the nature of influence of magnetic field on charge flow. According to the left-hand rule, a charge that moves along the line of magnetic field revolves around it in a direction that is dependent on whether the charge is positive or negative. Therefore, the effects of change of magnetic field action could accumulate with generations and cause minor genetic alterations that could lead to biological effects of a planetary scale, such as a global change or total extinction of certain species.



Magnetic dipole of Earth

Conclusion

In conclusion, the concept of magnetic dipole and magnetic dipole moment is very specific, however, it serves as a fundamental factor in many medicine-related techniques and procedures. Application of magnets for the purposes of medical examination has a rich history and has all grounds for further development. Even though modern technological progress in the field of magnetic screening allows us to ultimately explore the inside of human body, it still remains to be an actively developing branch of science. The power of tiny magnetic dipoles is still about to be fully explored, with more scientific breakthroughs in improving the quality of provided image, as well as elaboration of new methods of magnetic imaging.

References

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