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Extended Abstract

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Making magnetic monopole out of ordinary fields

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Since the ancient times, people have been wondering why there is no such thing as a magnetic pole, why every magnet, including the Earth itself, is a dipole with two poles, and why nobody succeeded to cut a magnetic dipole into two halves, carrying only one type of magnetic charge each, northern or southern. This fact becomes more interesting after one inspects the basic Maxwell equations of electrodynamics that readily admit inclusion of magnetic charges on the same ground as the well-known electric charges.
However, Paul Dirac established that a magnetic monopole cannot exist alone: it must be supplemented by what is now called the Dirac string–an infinitely thin solenoid, which canalizes all the magnetic lines of force diverging to the monopole outwards. Later he established that quantum mechanics states that if at least one magnetic monopole exists in the whole world, all electric charges would have discrete values. If we accept the charge of the quark, the smallest constituent of matter, to present the necessary quantum of charge, the corresponding value of the magnetic charge would be tremendous. However, up to now no magnetic charge has been discovered anywhere in nature. The reason may be that the magnetic charge is a very special object, called a pseudo-scalar, the scalar that changes its sign under reflection in a mirror. No fundamental object of this sort is known, but it can be readily constructed as the scalar product of a magnetic and electric fields. Therefore, to build a magnetic monopole one might try to combine multiplicatively an electric monopole with these two fields. However, the classical electrodynamics of Maxwell and Faraday admits only linear combinations of fields, the fields are independent and they do not influence each other. The situation becomes different when quantum electrodynamics by Feynman and Schwinger comes into play. In that theory the quantum of electromagnetic field, photon, creates virtually a pair of electrically charged particles, electron and positron, that later annihilate back to a photon. But, while existing in the state of the charged particles, the photon might interact with other electromagnetic fields and with itself. This is how, in quantum theory, electromagnetic fields interact between themselves. Correspondingly, the modified Maxwell equations become non-linear already in the vacuum. If we place a point-like electric charge into a combination of constant electric and magnetic fields with non-zero scalar product between them, the non-linear Maxwell equations produce the magnetic response, which carries a single point-like magnetic charge. Unlike the Dirac monopole proper, this one, cooked of ordinary fields, is not spherically symmetrical. It has two Dirac strings stretched along the above electric and magnetic fields, which merge to one if these fields are parallel. However, this modified monopole cannot serve to establish the discreetness of electric charges in Dirac's way. Hence the problem raised by his consideration remains unsolved, although a magnetic monopole has been made. All matter ever isolated to date, including every atom on the periodic table and every particle in the standard model, has zero magnetic monopole charge. Therefore, the ordinary phenomena of magnetism and magnets have nothing to do with magnetic monopoles.
nstead, magnetism in ordinary matter comes from two sources. First, electric currents create magnetic fields according to Ampère's law. Second, many elementary particles have an intrinsic magnetic moment, the most important of which is the electron magnetic dipole moment. (This magnetism is related to quantum-mechanical "spin".)

Mathematically, the magnetic field of an object is often described in terms of a multipole expansion. This is an expression of the field as the sum of component fields with specific mathematical forms. The first term in the expansion is called the monopole term, the second is called dipole, then quadrupole, then octupole, and so on. Any of these terms can be present in the multipole expansion of an electric field, for example. However, in the multipole expansion of a magnetic field, the "monopole" term is always exactly zero (for ordinary matter). A magnetic monopole, if it exists, would have the defining property of producing a magnetic field whose monopole term is non-zero. A magnetic dipole is something whose magnetic field is predominantly or exactly described by the magnetic dipole term of the multipole expansion. The term dipole means two poles, corresponding to the fact that a dipole magnet typically contains a north pole on one side and a south pole on the other side. This is analogous to an electric dipole, which has positive charge on one side and negative charge on the other. However, an electric dipole and magnetic dipole are fundamentally quite different. In an electric dipole made of ordinary matter, the positive charge is made of protons and the negative charge is made of electrons, but a magnetic dipole does not have different types of matter creating the north pole and south pole. Instead, the two magnetic poles arise simultaneously from the aggregate effect of all the currents and intrinsic moments throughout the magnet. Because of this, the two poles of a magnetic dipole must always have equal and opposite strength, and the two poles cannot be separated from each other.

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