Quantum Mechanics_magnetization

This article is about magnetization as it appears in Maxwell's equations of classical electrodynamics. For a microscopic description of how magnetic materials react to a magnetic field, see magnetism. For mathematical description of fields surrounding magnets and currents, see magnetic field.

In classical Electromagnetism, **magnetization** [1] or**magnetic polarization** is the vector field that expresses the density of permanent or inducedmagnetic dipole moments in a magnetic material. The origin of the magnetic moments responsible for magnetization can be either microscopic electric currents resulting from the motion of electrons inatoms, or the spin of the electrons or the nuclei. Net magnetization results from the response of a material to an external magnetic field, together with any unbalanced magnetic dipole moments that may be inherent in the material itself; for example, inferromagnets. Magnetization is not alwayshomogeneous within a body, but rather varies between different points. Magnetization also describes how a material responds to an appliedmagnetic field as well as the way the material changes the magnetic field, and can be used to calculate the forces that result from those interactions. It can be compared to electric polarization, which is the measure of the corresponding response of a material to an Electric field in Electrostatics. Physicists and engineers define magnetization as the quantity of magnetic moment per unit volume. It is represented by a vector M.

Contents

Definition

Magnetization can be defined according to the following equation:

$$\mathbf{M} = \frac{N}{V}\mathbf{m} = n\mathbf{m}$$

Here, **M** represents magnetization; **m** is the vector that defines the magnetic moment; V represents volume; and *N* is the number of magnetic moments in the sample. The quantity *N/V* is usually written as *n*, the number density of magnetic moments. The M-field is measured in amperes per meter (A/m) in SI units.[2]

Magnetization in Maxwell's equations

The behavior of magnetic fields (*B*, *H*), electric fields (*E*, *D*), charge density (*ρ*), andcurrent density (*J*) is described by Maxwell's equations. The role of the magnetization is described below.

Relations between B, H, and M

Main article: magnetic field

The magnetization defines the auxiliary magnetic field *H* as

$$\mathbf{B} = \mu_0(\mathbf{H} + \mathbf{M})$$ (SI units)

$$\mathbf{B} = (\mathbf{H} + 4\pi\mathbf{M})$$ (Gaussian units)

which is convenient for various calculations. The vacuum permeability μ_0 is, by definition, $4\pi \times 10^{-7}$ V·s/(A·m).

A relation between *M* and *H* exists in many materials. In diamagnets andparamagnets, the relation is usually linear:

$$\mathbf{M} = \chi_m \mathbf{H}$$

where χ_m is called the volume magnetic susceptibility.

In ferromagnets there is no one-to-one correspondence between *M* and *H* because of Magnetic hysteresis.

Magnetization current

The magnetization *M* makes a contribution to the current density *J*, known as the**magnetization current** or **bound (volumetric) current**:

$$\mathbf{J_m} = \nabla \times \mathbf{M}$$

and for the **bound surface current**:

$$\mathbf{K_m} = \mathbf{M} \times \hat{\mathbf{n}}$$

so that the total current density that enters Maxwell's equations is given by

$$\mathbf{J} = \mathbf{J_f} + \nabla \times \mathbf{M} + \frac{\partial \mathbf{P}}{\partial t}$$

where J_f is the electric current density of free charges (also called the **free current**), the second term is the contribution from the magnetization, and the last term is related to the electric polarization ***P***.

Magnetostatics

Main article: Magnetostatics

In the absence of free electric currents and time-dependent effects, Maxwell's equations describing the magnetic quantities reduce to

$$\nabla \cdot \mathbf{H} = -\nabla \cdot \mathbf{M}$$

$$\nabla \times \mathbf{H} = 0$$

Where Magnetization is volume density of magnetic moment. That is: if a certain volume has magnetization $\mathbf{M}$ then the volume element dV has a magnetic moment of $d\mathbf{m} = \mathbf{M}\,dV$

These equations can be solved in analogy with electrostatic problems where

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \times \mathbf{E} = 0$$

In this sense $-\nabla \cdot \mathbf{M}$ plays the role of a fictitious "magnetic charge density" analogous to the electric charge density ρ (see also demagnetizing field).

It is important to note that there is no such thing as a "magnetic charge," but that issue was still debated through the whole 19th century. Other concepts, that went along with it, such as the auxiliary field H, also have no real physical meaning in their own right. However, they are convenient mathematical tools, and are therefore still used today for applications such as modeling the magnetic field of the Earth.

Magnetization dynamics

Main article: Magnetization dynamics

The time-dependent behavior of magnetization becomes important when considering nanoscale and nanosecond timescale magnetization. Rather than simply aligning with an applied field, the individual magnetic moments in a material begin to precess around the applied field and come into alignment through relaxation as energy is transferred into the lattice.

Demagnetization

In addition to magnetization, there is also demagnetization. Demagnetization is the process by which the magnetic field of an object is reduced or eliminated.[3]The process of demagnetizing can be accomplished in many ways. One technique used for demagnetization is to heat the object above its Curie Temperature. The reason for this is that when a magnetic material is heated to its Curie Temperature, thermal fluctuations have enough energy to overcome the exchange interactions which cause ferromagnetism, and magnetic ordering is destroyed. One other way of achieving demagnetization is to use an electric coil. If the object is retracted out of a coil with alternating current running through it, the object's dipoles will become randomized and the object will be demagnetized.[4]

Applications of Demagnetization

One application of demagnetization is to eliminate unwanted magnetic fields. The reason for doing this is that magnetic fields can have unwanted effects on different devices. In particular magnetic fields can affect electronic devices such as cell phones or computers. If such a device is going to be coming into contact with other possibly magnetic objects, the magnetic fields might need to be reduced in order to protect the electronic device. Therefore demagnetization is sometimes used to keep magnetic fields from damaging electrical devices.[4]

See also

- Permeability (electromagnetism)
- Magnetic susceptibility
- Earth's magnetic field
- Geomagnetic reversal
- Geomagnetic excursion
- Orbital magnetization

The dictionary definition of magnetization at Wiktionary

Sources

1. ^ American spelling. The British spelling is **magnetisation**.
2. ^ "Units for Magnetic Properties". Lake Shore Cryotronics, Inc. Retrieved 2009-10-24.
3. ^ "Magnetic Component Engineering". Magnetic Component Engineering. Retrieved April 18, 2011.
4. ^ *a* *b* "Demagnetization". *Introduction to Magnetic Particle Inspection*. NDT Resource Center. Retrieved April 18, 2011.

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