Magnetic materials

The origin of magnetism lies in the orbital and spin motions of electrons and how the electrons interact with one another. Thebest way to introduce the different types of magnetism is to describe how materials respond to magnetic fields. This may be surprising to some, but all matter is magnetic. It's just that some materials are much more magnetic than others. The main distinction is that in some materials there is no collective interaction of atomic magnetic moments, whereas in other materialsthere is a very strong interaction between atomic moments

Types and properties

1. Diamagnetism

Diamagnetism is a fundamental property of all matter, although it is usually very weak. It is due to the non-cooperative behavior of orbiting electrons when exposed to an applied magnetic field. Diamagnetic substances are composed of atomswhich have no net magnetic moments (ie., all the orbital shells are filled and there are no unpaired electrons). However, when exposed to a field, a negative magnetization is produced and thus the susceptibility is negative. If we plot M vs H,

2. Paramagnetism

This class of materials, some of the atoms or ions in the material have a net magnetic moment due to unpaired electrons inpartially filled orbitals. One of the most important atoms with unpaired electrons is iron. However, the individual magneticmoments do not interact magnetically, and like diamagnetism, the magnetization is zero when the field is removed. In the presence of a field, there is now a partial alignment of the atomic magnetic moments in the direction of the field, resulting in a net positive magnetization and positive susceptibility.

3. Ferromagnetism

When you think of magnetic materials, you probably think of iron, nickel or magnetite. Unlike paramagnetic materials, the atomic moments in these materials exhibit very strong interactions. These interactions are produced by electronic exchange forces and result in a parallel or antiparallel alignment of atomic moments. Exchange forces are very large, equivalent to a field on the order of 1000 Tesla, or approximately a 100 million times the strength of the earth's field. The exchange force is a quantum mechanical phenomenon due to the relative orientation of the spins of two electron. Ferromagnetic materials exhibit parallel alignment of moments resulting in large net magnetization evenin the absence of a magnetic field.

4. Ferrimagnetism

In ionic compounds, such as oxides, more complex forms of magnetic ordering can occur as a result of the crystalstructure. One type of magnetic ordering is call ferrimagnetism.

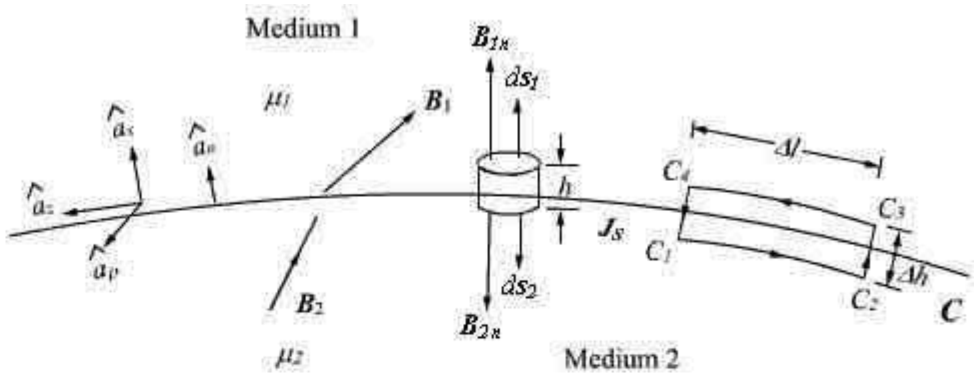
Magnetization

magnetic polarization is the vector field that expresses the density of permanent or induced magnetic 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 in atoms, 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.

Magnetic field in multiple media

Similar to the boundary conditions in the electro static fields, here we will consider the behavior of $\vec{B}$ and $\vec{H}$ at the interface of two different media. In particular, we determine how the tangential and normal components of magnetic fields behave at the boundary of two regions having different permeabilities.



Interface between two magnetic media

To determine the condition for the normal component of the flux density vector $\vec{B}$, we consider a small pill box P with vanishingly small thickness *h* and having an elementary area ΔS for the faces. Over the pill box, we can write

$$\oint_S \vec{B}.d\vec{s} = 0$$

Since h --> 0, we can neglect the flux through the sidewall of the pill box.

$$\therefore \int_{\Delta S} \vec{B}_1.d\vec{S}_1 + \int_{\Delta S} \vec{B}_2.d\vec{S}_2 = 0 \qquad d\vec{S}_1 = dS\hat{a}_n$$

$$d\vec{S}_2 = dS\left(-\hat{a}_n\right)$$

where

$$\therefore \int_{\Delta S} B_{1n}dS - \int_{\Delta S} B_{2n}dS = 0$$

$$B_{1n} = \vec{B}_1.\hat{a}_n \qquad B_{2n} = \vec{B}_2.\hat{a}_n$$

Since ΔS is small, we can write

$$(B_{1n} - B_{2n})\Delta S = 0$$

or, $$B_{1n} = B_{2n}$$

That is, the normal component of the magnetic flux density vector is continuous across the interface.In

vector form,

$$\hat{a}_n . (\vec{B}_1 - \vec{B}_2) = 0$$

To determine the condition for the tangential component for the magnetic field, we consider a closed path C asshown in figure 4.8. By applying Ampere's law we can write

$$\oint \vec{H} . d\vec{l} = I$$

Since h -->0,

$$\int_{c_1 - c_2} \vec{H} . d\vec{l} + \int_{c_3 - c_4} \vec{H} . d\vec{l} = I$$

We have shown in figure 4.8, a set of three unit vectors $\hat{a}_n$, $\hat{a}_t$ and $\hat{a}_\rho$ such that they satisfy $\hat{a}_t = \hat{a}_\rho \times \hat{a}_n$ (R.H. rule). Here $\hat{a}_t$ is tangential to the interface and $\hat{a}_\rho$ is the vector perpendicular to the surface enclosed by C at the interface