عناوین

۱- مواد پارامغناطیس

۲- مواد فرومغناطیس

نقش اسپین الکترونها

Constituent atoms or molecules of paramagnetic materials have permanent magnetic moments (dipoles), even in the absence of an applied field.

The permanent moment generally is due to the spin of unpaired electrons in atomic or molecular electron orbitals.

In pure paramagnetism, the dipoles do not interact with one another and are randomly oriented in the absence of an external field due to thermal agitation, resulting in zero net magnetic moment.

When a magnetic field is applied, the dipoles will tend to align with the applied field, resulting in a net magnetic moment in the direction of the applied field. In the classical description, this alignment can be understood to occur due to a torque being provided on the magnetic moments by an applied field, which tries to align the dipoles parallel to the applied field. However, the true origins of the alignment can only be understood via the quantum-mechanical properties of spin and angular momentum.

If there is sufficient energy exchange between neighbouring dipoles, they will interact, and may spontaneously align or anti-align and form magnetic domains, resulting in ferromagnetism (permanent magnets) or antiferromagnetism, respectively. Paramagnetic behavior can also be observed in ferromagnetic materials that are above their Curie temperature, and in antiferromagnets above their Néel temperature. At these temperatures, the available thermal energy simply overcomes the interaction energy between the spins.

In general, paramagnetic effects are quite small: the magnetic susceptibility is of the order of 10^{-3} to 10^{-5} for most paramagnets, but may be as high as 10^{-1} for synthetic (مصنوعى) paramagnets such as ferrofluids.

قانون کوری در مواد پارامغناطیس

For low levels of magnetization, the magnetization of paramagnets follows what is known as Curie's law, at least approximately. This law indicates that the susceptibility, χ, of paramagnetic materials is inversely proportional to their temperature, i.e. that materials become more magnetic at lower temperatures. The mathematical expression is:

$$\boldsymbol{M} = \chi \boldsymbol{H} = \frac{C}{T} \boldsymbol{H}$$

where:

M is the resulting magnetization, measured in amperes/meter (A/m),

χ is the volume magnetic susceptibility (dimensionless),

H is the auxiliary magnetic field (A/m),

T is absolute temperature, measured in kelvins (K),

C is a material-specific Curie constant (K).

Curie's law is valid under the commonly encountered[*1] conditions of low magnetization ($\mu_B H \lesssim k_B T$), but does not apply in the high-field/low-temperature regime where saturation of magnetization occurs ($\mu_B H \gtrsim k_B T$) and magnetic dipoles are all aligned with the applied field. When the dipoles are aligned, increasing the external field will not increase the total magnetization since there can be no further alignment.

Materials that are called "paramagnets" are most often those that exhibit, at least over an appreciable[*2] temperature range, magnetic susceptibilities that adhere[*3] to the Curie or Curie–Weiss laws. In principle any system that contains atoms, ions, or molecules with unpaired spins can be called a paramagnet, but the interactions between them need to be carefully considered.

The **Curie–Weiss law** describes the magnetic susceptibility χ of a ferromagnet in the paramagnetic region above the Curie point:

$$\chi = \frac{C}{T - T_c}$$

مواد فرومغناطیس

Ferromagnetism is the basic mechanism by which certain materials (such as iron) form permanent magnets, or are attracted to magnets.

انواع مختلف مواد مغناطیسی

In physics, several different types of magnetism are distinguished. Ferromagnetism (along with the similar effect ferrimagnetism) is the strongest type and is responsible for the common phenomena of magnetism in magnets encountered in everyday life.

Substances respond weakly to magnetic fields with three other types of magnetism, paramagnetism, diamagnetism, and antiferromagnetism, but the forces are usually so weak that they can

only be detected by sensitive instruments in a laboratory. An everyday example of ferromagnetism is a refrigerator magnet used to hold notes on a refrigerator door. The attraction between a magnet and ferromagnetic material is "the quality of magnetism first apparent to the ancient world, and to us today“

تعریف آهنربای دائمی

Permanent magnets (materials that can be magnetized by an external magnetic field and remain magnetized after the external field is removed) are either ferromagnetic or ferrimagnetic, as are the materials that are noticeably attracted to them.

گستره و کاربرد مواد فرومغناطیس

Only a few substances are ferromagnetic. The common ones are iron, nickel, cobalt and most of their alloys, and some compounds of rare earth metals.

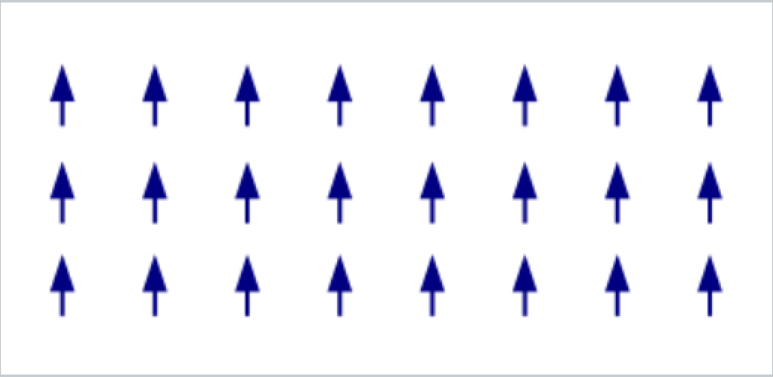
Ferromagnetism is very important in industry and modern technology, and is the basis for many electrical and electromechanical devices such as electromagnets, electric motors, generators, transformers, and magnetic storage such as tape recorders*, and hard disks.

تاریخچه مواد فرومغناطیس و چگونگی شناسایی آنها از مواد فری و آنتی فرومغناطیس

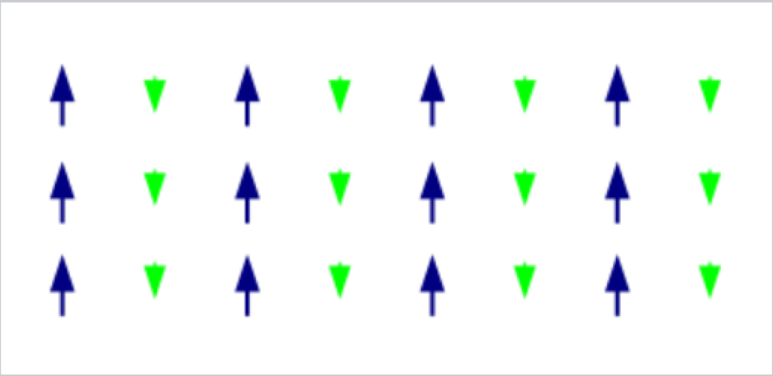
Historically, the term ferromagnetism was used for any material that could exhibit spontaneous magnetization: a net magnetic moment in the absence of an external magnetic field. This general definition is still in common use.

However, in a landmark* paper in 1948, Louis Néel showed there are two levels of magnetic alignment that result in this behavior.

One is ferromagnetism in the strict sense, where all the magnetic moments are aligned. The other is ferrimagnetism, where some magnetic moments point in the opposite direction but have a smaller contribution, so there is still a spontaneous magnetization.

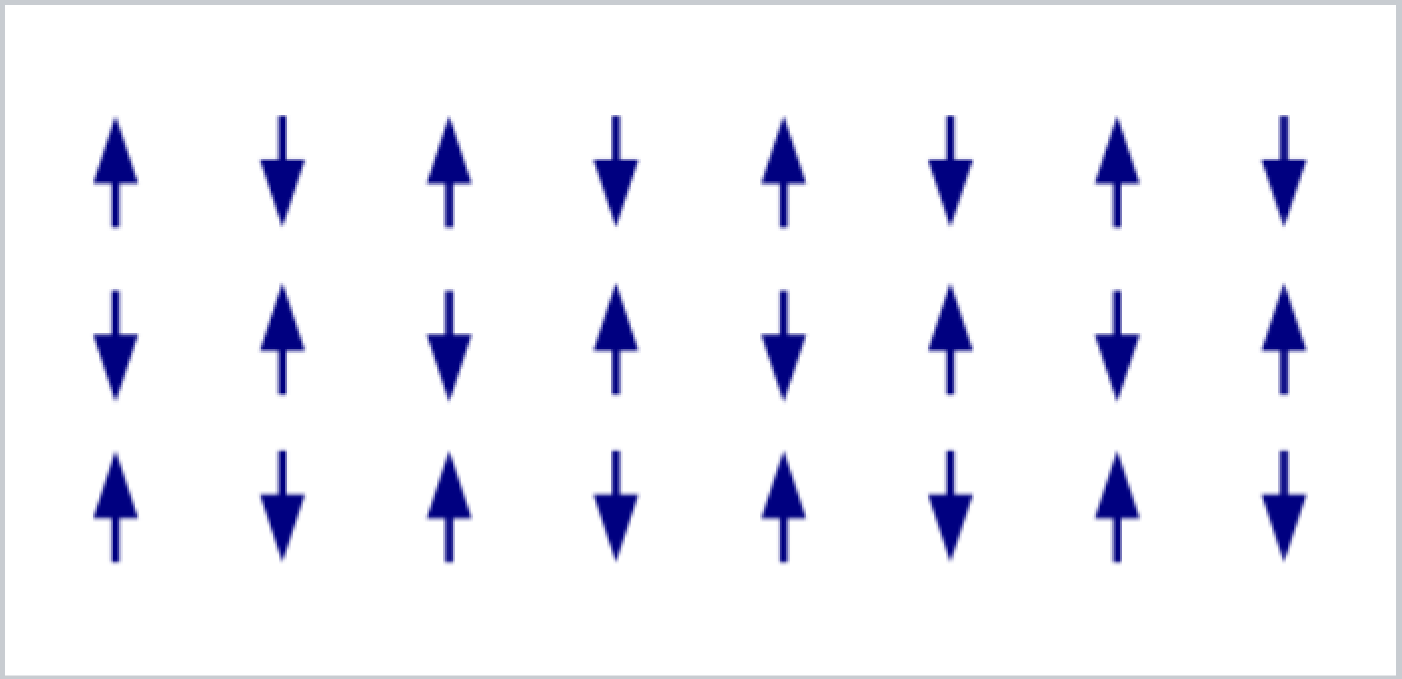


Ferromagnetic ordering in the strict sense



Ferrimagnetic ordering

In the special case where the opposing moments balance completely, the alignment is known as antiferromagnetism; but antiferromagnets do not have a spontaneous magnetization.



Antiferromagnetic ordering

In next slide the table lists a selection of ferromagnetic and ferrimagnetic compounds, along with the temperature above which they cease(متوقف شدن) to exhibit spontaneous magnetization (see Curie temperature). Ferromagnetism is a property not just of the chemical make-up(آرایش شیمیایی) of a material, but of its crystalline structure and microstructure. There are ferromagnetic metal alloys whose constituents are not themselves ferromagnetic, called Heusler alloys, named after Fritz Heusler. Conversely(برعکس) there are non-magnetic alloys, such as types of stainless(ضد زنگ) steel(فولاد), composed almost exclusively(انحصاراً) of ferromagnetic metals.

Curie temperatures for some crystalline ferromagnetic materials[6][7]

Material	Curie temp. (K)
Co	1388
Fe	1043
Fe_2O_3[a]	948
$FeOFe_2O_3$[a]	858
$NiOFe_2O_3$[a]	858
$CuOFe_2O_3$[a]	728
$MgOFe_2O_3$[a]	713
MnBi	630
Ni	627
MnSb	587
$MnOFe_2O_3$[a]	573
$Y_3Fe_5O_{12}$[a]	560
CrO_2	386
MnAs	318
Gd	292
Tb	219
Dy	88
EuO	69

a. ^ a b c d e f g Ferrimagnetic material