Magnetic Materials: section 27.5 of Tipler.

When a magnetic field (called B) is applied to a material, the material can generate its own magnetic field, called the M. The relationship between M and B is given in terms of the magnetic susceptibility, χ. The equation is a vector equation:

$$\vec{M} = \frac{\chi \vec{B}}{\mu_0}$$

If the susceptibility is positive, the magnetization, M, is parallel to the external field B, the material is paramagnetic, and will be attracted to external fields. Like your magnet is attracted to your refrigerator door, or the leg of a chair. The magnet produces a B field around it, and the paramagnets align to it, and attract.

Some materials have negative susceptibility. They produce an M field opposed to any external field. They are called diamagnets. Most diamagnets are very weak at room temperature, but at low temperature all kinds of rich magnetic effects get stronger. Superconductors are perfect diamagnets: they oppose all external fields, such that the net field inside the superconductor is zero[1] and the susceptibility is exactly minus one. Generally, susceptibilities are ten to the negative five, so very small.

Both para- and dia- magnets should go to zero M (no field) when B is removed. Meaning, they do not remember. Only special materials (very few) can be what we commonly call "magnets".

Ferromagnets are permanent magnets, or what most people just call "magnets". When an external field is applied, the material will produce its own field aligned to the external field (just like a paramagnet), but unlike a para or dia-magnet, when the external field is removed, the

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[1] This is nearly true: the superconductor opposes all change in field. If the superconductor was in an external field when it's temperature was lowered, so it felt an external field when it was "normal" and then it became a superconductor, the superconductor will oppose all changes to this field. If you really want to know all about superconductors, and demos, there is an excellent explanation online on youtube, although the handwriting is potato quality:
https://www.youtube.com/watch?v=zwFsGpPr1DI

ferromagnet keeps some M field going. This can be a very small fraction of the full field, meaning the ferromagnet is “stronger” in the presence of an external field.

How hard (or easy) it is to counter the remaining field is called the “coercivity” of the material. High coercivity materials are also called “hard” ferromagnets, and useful for magnetic memory (such as hard disk drives). “Soft” ferromagnets act more like paramagnets, to reinforce an external field, so they are useful in transformers[2].

Somewhat more technical view of Paramagnetism and Diamagnetism, Mostly from Wikipedia:

Paramagnetic materials have a small, positive susceptibility to magnetic fields. These materials are slightly attracted by a magnetic field and the material does not retain the magnetic properties when the external field is removed. Paramagnetic properties are due to the presence of some unpaired electrons, and from the realignment of the electron paths caused by the external magnetic field. Paramagnetic materials include magnesium, molybdenum, lithium, and tantalum.

Unlike ferromagnets, paramagnets do not retain any magnetization in the absence of an externally applied magnetic field because thermal motion randomizes the spin orientations. Some paramagnetic materials retain spin disorder at absolute zero, meaning they are paramagnetic in the ground state. Thus the total magnetization drops to zero when the applied field is removed. Even in the presence of the field there is only a small induced magnetization because only a small fraction of the spins will be oriented by the field. This fraction is proportional to the field strength and this explains the linear dependency. The attraction experienced by ferromagnetic materials is non-linear and much stronger, so that it is easily observed, for instance, by the attraction between a refrigerator magnet and the iron of the refrigerator itself.

Diamagnetism is the property of an object or material that causes it to create a magnetic field in opposition to an externally applied magnetic

[2] Not robots that turn into cars, but electric devices to change voltage. You cell phone charger which plugs into the wall contains a transformer to take the 120 volt wall voltage down to, say 5 or 10 volts to your phone. If you feel it, it will be warm.

field. It is a quantum mechanical effect that occurs in all materials; where it is the only contribution to the magnetism the material is called a *diamagnet*. Unlike a ferromagnet, a diamagnet is not a permanent magnet. Its magnetic permeability is less than μ_0 (the permeability of free space). In most materials diamagnetism is a weak effect, but a superconductor repels the magnetic field entirely, apart from a thin layer at the surface.