St John Baptist De La Salle Catholic School, Addis Ababa

Notes on Magnetism

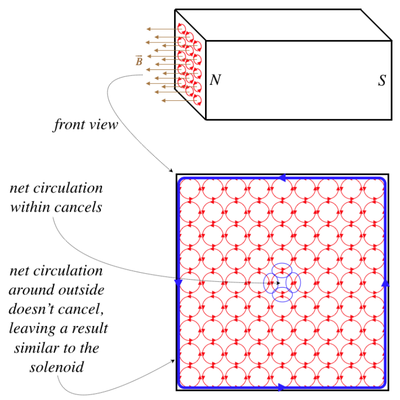
December 16, 2024

Magnetic Materials

As with any phenomenon that requires an understanding of what is going on at a microscopic level, magnetism inside of materials like bar magnets is very complicated. We'll look at a greatly-simplified version of it here, but keep in mind that a fuller understanding can only be achieved through quantum theory.

We now know that there are no "magnetic particles" comprising a bar magnet – its magnetic field can only be created by moving charges. But unlike an electromagnet, bar magnets are not plugged into some emf source, so where does the moving charge come from? The atoms that comprise the material of course include lots of charges, and these charges are moving in manners that resemble magnetic dipoles – electrons are orbiting nuclei in more-or-less circular loops, and electrons also have a quantum-mechanical property called "spin" that gives them their own magnetic moments as well.

We will not concern ourselves too much with the specific source of the magnetic moments of these particles, but we will instead just focus on the fact that each particle has its own magnetic moment. In the case of a bar magnet, these dipoles tend to be permanently aligned. This property is called ***ferromagnetism***. Only a few materials have this property: iron (thus "ferro"), nickel, cobalt, many of their alloys, and some of the rare earth metals. [Technically, these alignments occur in chunks, called "***domains***," within the magnet, and the degree to which the magnet is magnetized is determined by how much certain domains "swallow-up" others, creating more broadly-coordinated alignments of dipoles.]



It should be clear how two bar magnets attract each other. One is a magnetic field source, and the other is a magnetic dipole that experiences the non-uniform field of the other. The field diverges as it emerges from one magnet, and the dipole of the other magnet, if the poles are aligned, reacts by feeling a force in the direction where the field gets stronger.

Some metals, while their particle dipole moments are not permanently aligned, have the property that their particles are free to rotate their magnetic moments. When an external field is applied, their particles then align, making them magnetized. When the field is removed, the random alignments return. This property is known as paramagnetism.

Advanced Reading on Ferromagnetism & Paramagnetism

(i) Ferromagnetism relies primarily upon the spin source of magnetic moment, and very little on the orbital source, while paramagnetism relies upon both.

(ii) Ferromagnetic materials remain magnetized after a strong applied magnetic field aligns the domains, which remain aligned thanks to anomalies in the crystal structure which "snag" the domains and hold them in an aligned orientation.

(iii) Ferromagnets can be demagnetized ("degaussed") by relieving these snags. This is most easily done by raising the temperature to a critical temperature known as the Curie temperature, at which magnetic domain "snags" are no longer possible and the substance has zero ferromagnetism. Other methods for degaussing include applying rapidly-changing magnetic fields (which "shake" the domains into random orientations) and pounding on the magnet so that vibrations cause the domains to un-snag.

Further reading: ***Four Different Kinds of Magnetism***
https://physics.kebede.org/assets/notes/magnetism/nature/magnetism.pdf