Bob's TechTalk #43

by Bob Eckweiler, AF6C

Permanent Magnetics

Last month we looked at the inductor and how it uses its ability to store and release energy in a magnetic field to oppose the change of current flow in a circuit. This month we are going to back up a bit and talk about magnets in general, specifically permanent magnets.

Permanent magnets come in numerous sizes and shapes. Figure 1a is a simple bar magnet; its ends are the poles of the magnet and one is named the north pole (N) and the other is the south pole (S). You cannot isolate the poles; if you cut the magnet in half (Fig. 1b) you get two weaker magnets each with a north and south pole.

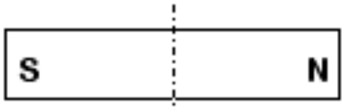

Fig 1a

Fig 1b

When a piece of material is brought near a bar magnet it may be drawn to one of the poles of the magnet, or if shape and size permit, to both poles. This is true of only certain materials called ferromagnetic materials such as iron and cobalt. If the material is also a magnet then the attraction will be strong as long as the two poles are of opposite polarity. However if two like poles are brought in close proximity they will repel each other. The force of attraction or repulsion of two magnetic poles is proportional to the magnetic strength of the poles and inversely proportional to the square of the distance between them. That is, the force is four times stronger at 1/2 inch than at 1 inch.

One of the first uses of a permanent magnet was as a compass. People observed that if you floated a small magnetic needle in a liquid it orients itself in a north-south direction. Scientists discovered that the earth itself is a large magnet with its poles near (but not on) the axis of the earth's rotation. The floating magnetized needle is reacting to the magnetic earth. The pole that points north on the compass magnet is named the north pole and the other pole is named the south pole. Since opposite poles attract, the earth's magnetic pole in the north is actually the earth's south pole.

The Magnetic Field:

Since a magnetic force acts over a distance, there must be a magnetic field created by the magnet. This field can be traced by moving a compass around a bar magnet. In figure 2 the compass needle points along the magnetic field path as depicted by the bold arrows. The direction of the field outside the magnet is defined as going from the north pole to the south pole. The magnetic field may be seen by placing the bar magnet below a sheet of paper and placing iron filings on the paper. Figure 3.

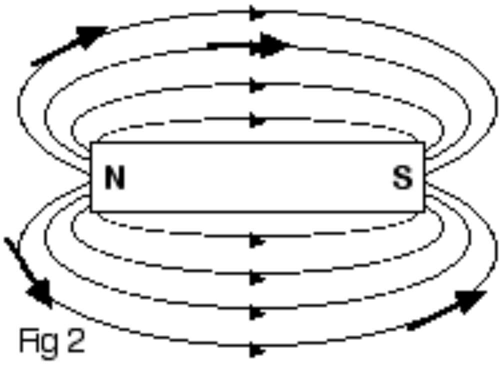

Fig 2

Magnetic Flux:

The lines depicted in figure 2 represent the magnetic field surrounding the bar magnet. In reality there are an infinite quantity of lines and these lines are called the magnetic flux. In the early days the strength of a magnet was symbolized by the amount of lines drawn and the "line" became the unit of magnetic flux. Today the flux is measured by the maxwell and the weber where 1 weber = 100 million maxwells. It should be noted that flux is a vector quantity as it not only has magnitude but also direction.

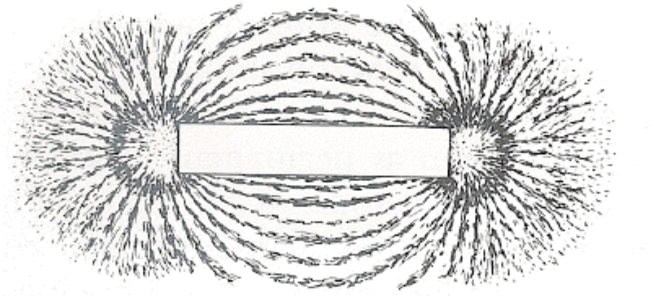

Figure 3 – Iron filings show magnetic field

Flux Density:

As depicted in Figure 2 the lines are closer in some places and farther apart in others. The amount of flux that passes through a given area 'a' is the flux density and is measured in gauss, where one gauss is one weber per square meter. Figure 4 shows the concept of Flux density.

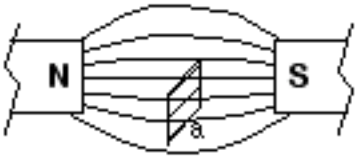

Fig 4

The units of magnetism mentioned above are all named for scientists of the late 18th and 19th centuries. The weber is named for Wilhelm Eduard Weber (1804 - 1891), the maxwell for James Clerk Maxwell (1831 - 1879) and the gauss for Karl Friedrich Gauss (1777 - 1855).

Magnetic Materials:

In the realm of magnetism, material may be divided into three categories: diamagnetic, paramagnetic and ferromagnetic. Which category a particular material fall into depends on the nature of the atoms that make it up. All atoms have electrons moving in orbit around the nucleus. These electrons also spin on their own axis. Since a moving electron is a form of current, magnetic fields are generated by these motions.

In a diamagnetic material these fields tend to cancel and the material shows little or no magnetic tendencies. Nor do they tend to distort the magnetic field passing through them. (In actuality they very weakly tend to oppose the field.) Lead, silver and water are three diamagnetic materials.

In a paramagnetic material the fields created by the atoms only partially cancel. But since the atoms are distributed randomly, the material creates no net magnetic field. However, when subject to an external magnetic field the atoms align and a weak magnetic field is created that adds slightly to the applied field within the material. Aluminum is a common paramagnetic material.

In a ferromagnetic material the magnetic properties of the atoms reinforce one another resulting in strong magnetic fields. Atoms in a ferromagnetic material respond in groups called domains made up of numerous atoms that orient themselves parallel to each other. Since the domains are randomly oriented throughout the material, the net field tends to cancel. However, when the ferromagnetic material is subject to an external magnetic field the domains align and the flux density within the material becomes much higher than the flux due only to the external field. Also, when the external field is removed the domains tend to remain in their current orientation resulting in residual magnetism in the material. Thus ferromagnetic material can be magnetized and made a permanent magnet.

Magnets may be damaged or destroyed by a large physical shock. The shock or even a violent vibration tends to randomize the orientation of the atoms in the magnetic material. Also if a ferromagnetic material is heated to a point above its “Curie Temperature” it will lose its magnetic properties due to the thermal agitation of the atoms breaking up and randomizing the orientation of the atoms in the domains.

Heating ferromagnetic material above the Curie point and then subjecting it to a strong magnetic field while it cools is a process for making a permanent magnet.

Summary:

This brief understanding of magnetic materials will help when we discuss electromagnets. The understanding of magnetic fields, flux and flux density will make the next section easier to comprehend.

73, from AF6C

This article originally appeared in the October 2010 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.