01. Concepts and Principles

Moving Charges

All charged particles create electric fields, and these fields can be detected by other charged particles resulting in electric force. However, a completely *different* field, both qualitatively and quantitatively, is created when charged particles move. This is the magnetic field. All *moving* charged particles create magnetic fields, and all *moving* charged particles can detect magnetic fields resulting in magnetic force. *This is in addition to the electric field that is always present surrounding charged particles*.

This should strike you as rather strange. Whenever a charged particle begins to move a completely new field springs into existence (distributing business cards throughout the universe). Other charged particles, if they are at rest relative to this new field, *do not notice this new field* and do not feel a magnetic force. Only if they move relative to this new field can they sense its existence and feel a magnetic force. It's as if only while in motion can they read the business cards distributed by the original moving charge, and only while in motion does the original charge distribute these business cards in the first place! Does it sound strange yet?

Why the magnetic field exists, and its relationship to the electric field and relative motion will be explored later in the course. For now, we will concentrate on learning how to calculate the value of the magnetic field at various points surrounding moving charges. Next chapter, we will learn how to calculate the value of the magnetic force acting on *other* charges moving relative to a magnetic field.

Permanent Magnets

I claimed above that the magnetic field only exists when the source charges that create it are moving. But what about permanent magnets, like the ones holding your favorite physics assignments to your refrigerator? Where are the moving charges in those magnets?

The simplest answer is that the electrons in "orbit" in each of the atoms of the material create magnetic fields. In most materials, these microscopic magnetic fields are oriented in random directions and therefore cancel out when summed over all of the atoms in the material. In some materials, however, these microscopic magnetic field (large enough to interact with the microscopic magnetic fields present in your refrigerator door). Although this is a gross simplification of what actually takes place, it's good enough for now.

The magnetic properties of real materials are extremely complicated. In addition to the orbital contribution to magnetic field, individual electrons and protons have an intrinsic magnetic field associated with them due to a property called *spin*. Moreover, even neutrons, *with no net electric charge*, have an intrinsic magnetic field surrounding them. To learn more about the microscopic basis of magnetism, consider becoming a physics major....

Electric Current

Moving electric charges form an electric current. We will consider the source of all magnetic fields to be electric current, whether that current is macroscopic and flows through a wire or whether it is microscopic and flows "in orbit" around an atomic nucleus.

Thd simplest source of magnetic field is electric current flowing through a long, straight wire. In this case, the magnetic field at a particular point in space is given by the relation,

pic

where

- m0 is the *permeability of free space*, a constant equal to 1.26 x 10^{-6} Tm/A.
- i is the source current, the electric current that creates the magnetic field, and is measured in amperes (A). One ampere is equal to one coulomb of charge flowign through the wire per second.(We will always enter the current as a positive value in this relation. The definition of (t hat) below will be used to specify the correct direction of the field.)
- r is the distance between the source current and the point of interest.
- (t hat) is the unit vector that is *tangent* to a circle centered on the source current, and located at the point of interest. To determine the sense of (t hat), place your thumb in the direction of current flow. The sense in which the fingers of your *right*

hand curl is the sense of (t hat). (For example, for current flowing out of the page, (t hat) is counterclockwise.)

If the source of the magnetic field is more complicated than long, straight current-carrying wires, then a more general relationship is needed. The magnetic field at a particular point in space, from any current distribution, is given by the relation,

pic

where

- (pic) is an infinitesimally small portion of current-carrying wire.
- (r hat) is the unit vector that points *from* the small portion of current-carrying wire *to* the point of interest.
- The integral is over the entire length of wire.

Paul D’Alessandris (Monroe Community College)