# Magnetic Fields

## I. Magnetic Field and Magnetic Field Lines

**A.** The concept of the magnetic field can be developed in a manner similar to the way we developed the electric field. The magnitude of the magnetic field at a particular point in space is found by using a moving charged particle and determining the maximum force exerted on the particle for a given speed.

$$B = \frac{F_{MAX}}{q\,v}$$

The magnetic field vector lies along the direction in which the moving charged particle experiences no additional force due to its motion (no force if we remove electric fields, gravity, etc.) with the direction of the vector given by the right hand rule.

**B.** We can build a graphical picture of the magnetic field (magnetic field lines) in a manner similar to our work with electric fields. However, there are some important differences due to the nature of the vector cross product that you need to understand.

**Similarities To Electric Field Diagrams:**

**1.** Magnetic field lines leave the north pole (like electric field lines from a positive charge) and terminate on the south pole of a magnet (like electric field lines on a negative charge).

**2.** Magnetic field lines can never cross (the magnetic field has a single value at every point is space),

**3.** The density of magnetic field lines is proportional to the strength of the magnetic field.

The easiest way to map the magnetic field is to use iron fillings. These act like little magnets and align with the field. A compass can then be used to determine the direction of the arrow. Also, the strength of the magnetic field is obtained since more iron filings will be attracted to regions of higher magnetic field.

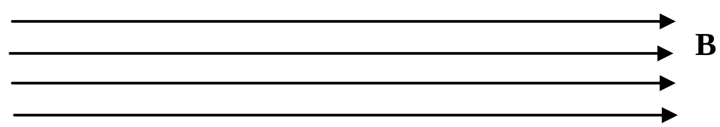
**Differences:**

1. A graph of the magnetic field lines doesn't completely specify the force on a charged particle. This is because the force also depends on the velocity of the particle. Stationary particles experience no magnetic force at all!

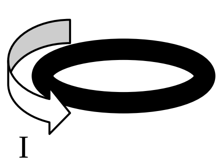
2. A magnetic field line **<u>DOES NOT</u>** point in the direction of the force applied on a moving charged particle.  If fact, a charged particle moving the direction of the magnetic field line experiences **<u>NO</u>** magnetic force. The non-zero force experienced by any moving charge will always be perpindicular to the magnetic field lines.

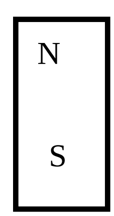
3. We find that the graphs of the magnet field lines always show circulation (rotation) and never flow!  More evidence that their is no point source of magnetism.

**EXAMPLE:** The following **can not be** a graph of the magnetic field because it has flow and no circulation.




**EXAMPLE:** The magnetic field diagram for a magnetic dipole (the simplest magnetic source known).




**Current Loop**

**Permanent Magnet**

**C. Source of Magnetic Fields - ________________________________**

## II. Ampere's Law

For any closed path, the sum of the product of the length of a segment of the path times the component of the magnetic field parallel to the past is equal to the current that penetrates the surface area bounded by the path.

To use Ampere's Law to calculate a magnetic field, you usually must know the shape of the magnetic field lines so you can choose a special path where the magnetic field is constant and can be pulled outside the sum.

**Case 1:** Current Carrying Wire

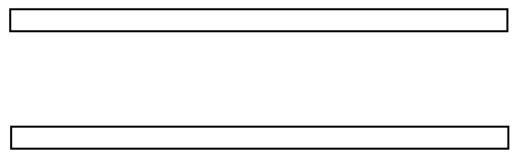
**Case 2:** An Infinitely Long Solenoid

**Case 3:** A Torroid

III. Force Between Two Current Carrying Wires

When two current carrying wires are placed parallel to each other they will apply a magnetic force upon each other that causes them to either be repelled or attracted to each other depending on the direction of the currents.

**Case:** What is the magnetic force per length for the two current wires shown below:



**IV.** Torque On A Current Carrying Loop

Consider the current carrying rectangular loop in a magnetic field shown below:

What is the net magnetic force on the loop?

What is the torque applied by the magnetic field upon the wire?

While we did this for a rectangular loop, it is a general result regardless of the loops shape. If the loop has N-turns then the torques on each turn sums to increase the total torque by a factor N.