Magnetism

I. Permanent Magnets

A. Over 2000 years ago in Turkey, people discovered that rocks of iron ore would apply a force on each other. These rocks were called magnets due to their discovery near the town of magnesia.

B. Several interesting facts concerning these rocks were discovered**:**

1. If a rod of iron touched these rocks, then it would become a magnet and begin interacting with these rocks. The rod was said to be have been magnetized.

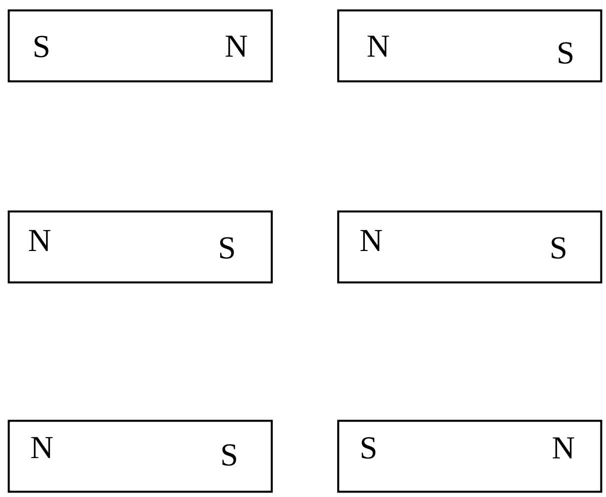
2. If the magnetized rod was placed on a leaf and floated on water, the rod would always align itself so that it pointed approximately in the North/South direction on the Earth.

Thus, people were using compasses for navigation for nearly two thousand years before we developed a theory of magnetism in the 1800's. We now know that these phenomena are because the Earth is a big magnet due to currents inside the Earth.

3. After marking the side of the rod that pointed in the northern direction as north and the side that pointed in the southern direction as south, people discovered that

a) the north side (pole) of the magnet repelled the north pole and attracted the south pole of another magnet.

b) the south pole of a magnet repelled the south pole of another magnet.



Question: From the discussion above, what type of magnetic pole is near the Earth's North Pole?

4. Cutting a magnet in half will produce two complete magnets.

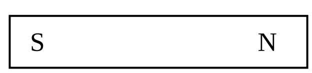
This discovery is probably far more intriguing today than it was long ago since it implies that the cause of magnetism is not a point source (like a point charge) but an extended source (a current loop). The search for a point source of magnetism (magnetic monopole) is an active field of physics research. We will discuss this further when we get to Gauss' Law for Magnets.

Summary: A considerable amount of empirical information about magnetism was discovered using permanent magnets. This allowed for the construction of some useful devices using permanent magnets long before any theory of magnetism existed. However, the connection between the phenomena of electricity (discovered in Greece) and magnetism (discovered in Turkey) prevented people from developing motors, generators, stronger magnets (electromagnets), and electrical power. It was the development of the battery in the late 1700's that would begin the age of electricity. Thus, many of the conventions concerning magnets (using N/S instead of +/-) are historical in nature.

II. Mapping Magnetic Fields

Now that we know that magnets can apply a force upon another magnet or a compass, we can think about describing magnets with a vector field like we did with electric fields.

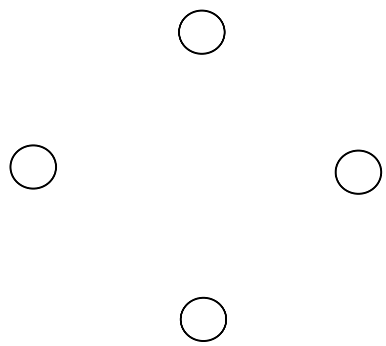
The direction of the field produced by a magnet can be mapped using a compass and drawing an arrow at each point in space in the direction that the compass points.



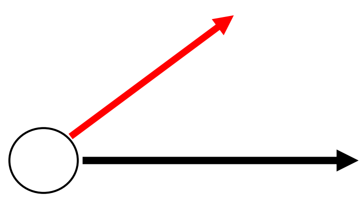
III. Magnetic Force

A. Operational Definition -

The **EXTRA Force** that a **<u>CHARGED OBJECT</u>** acquires when it is set in **<u>Motion</u>** is called the **<u>Magnetic Force</u>**.



B. Force On A Moving Charge – "Lorentz Force Law For Magnets"



Magnitude:

Direction:

C. **Units –**

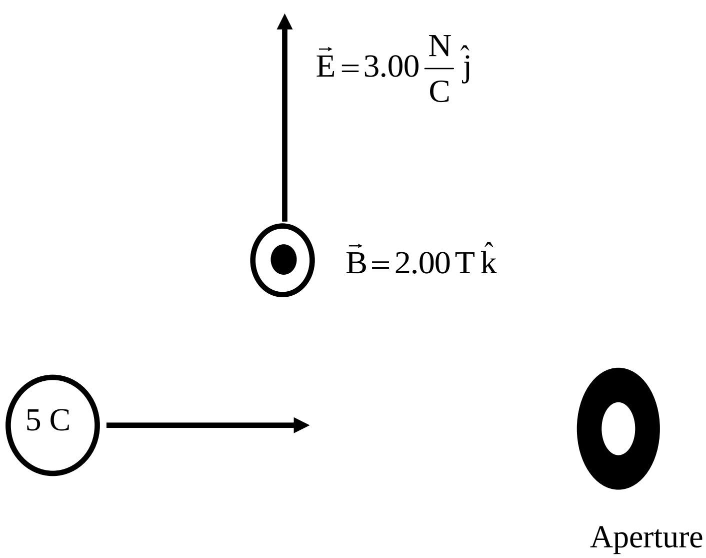
Note: A 1.00 T field is an extremely large magnetic field so physicists and engineers usually work in Gauss. The conversion factor is

Thus, you must convert all magnetic fields from Gauss to Tesla before using the Lorentz Force Law for Magnets.

EXAMPLE: Wien Filter "Cross Field Analyzer"

Our problem involves a very useful device that allows use to select charged particles of a particular velocity (i.e. it's a velocity selector)!

A 5.00 C charged object is placed in an electric field of 3.00 N/C in the +y direction and a magnetic field of 2.00 T in the +z direction as shown below



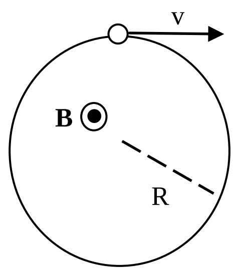
a) What is the net force on the object when the object is stationary?

b) What is the net force when the object has a velocity of 3.00 m/s in the +x direction?

c) Determine the velocity required by the object to travel undeflected through the aperture.

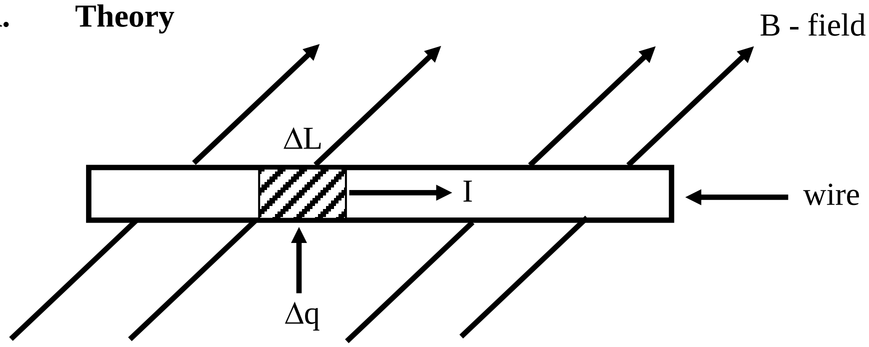
EXAMPLE: Charged Particle In A Perpendicular Magnetic Field (Mass Spectrometer)

A charged particle traveling in a uniform magnetic field perpendicular to its velocity will travel in uniform circular motion.



IV. Magnetic Force On A Current Carrying Wire

A. Theory



The magnetic force on a differential amount of moving charge, Δq, in the wire is

$$\Delta F =$$

Using the definition of velocity, $v \equiv \frac{\Delta L}{\Delta t}$, we have

$$\Delta F =$$

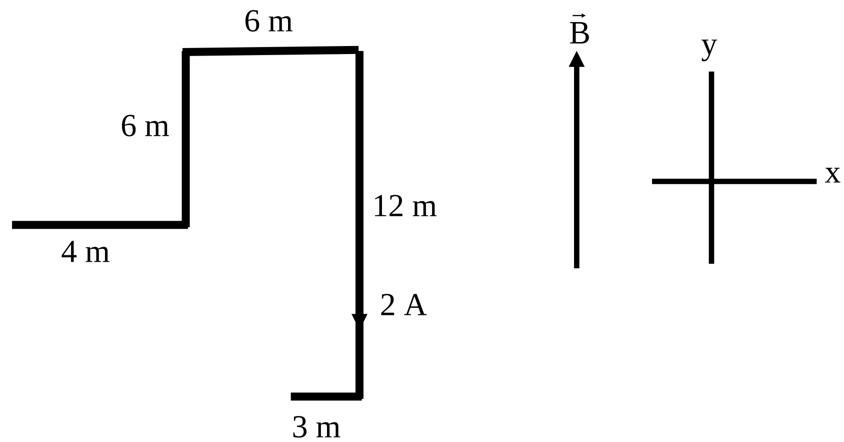
$$\Delta q\left(\frac{\Delta L}{\Delta t}\right) = \left(\frac{\Delta q}{\Delta t}\right)\Delta L$$

Substituting this result and using the definition of current, we have

$$\Delta F =$$

The total force on the wire is then found by summing up the force on each element of the wire. For a straight wire and constant magnetic field, we find

EXAMPLE: What is the force exerted by a 5.00 T magnetic field in the +y-direction upon the 25.0 meter long wire shown below when 2.00 A of current is flowing in the wire.



Solution: