Lesson 15: Magnetic Fields

We can imagine a magnetic field surrounding a magnet in much the same way that we did for electrical charges.

- One of the biggest differences is that **electrical charges can be isolated from each other** (a negative charge can be sitting all alone), while **magnetic poles must come in pairs** (north and south).
  - So when you draw diagrams of magnetic fields, they will more closely resemble the kinds of diagrams we did with multiple electric charges and parallel plates.
- We will continue to use the concept of "field" to explain how one magnet can exert a force on another magnet by an interaction between magnetic fields.
  - This is action at a distance, like gravity and electric charges.

Did you know?
There are some theories in modern physics that indicate that it should be possible (even though it's never been done) to isolate a north pole from a south pole. The ***di***poles would become ***mono***poles.

At this point it would be valuable to compare the three kinds of fields we have examined in Physics 20 and 30.

- Since they are all fields they all share similarities, but they are not the same.
- You should be able to discuss these similarities and differences.

Magnetic Fields	Gravitational Fields	Electric Fields
Strong field.	Weakest of all fields.	Strong field.
Not directly calculated in Physics 30 (although we do measure it indirectly).	Calculated using an inverse square law (*Newton's Universal Law of Gravitation*).	Calculated using an inverse square law (*Coulomb's Law*).
Attraction or Repulsion.	Always attraction.	Attraction or Repulsion.
Directly related to the magnet involved.	Directly related to the masses involved.	Directly related to the charges involved.
Individual poles can never be separate from each other.	Individual masses are separate from each other.	Individual charges are separate from each other.
Follows inverse square law near the magnet, but follows an inverse cubed law further away, so that the field becomes exponentially weaker as separation increases.	Follows inverse square law, so that the field becomes exponentially weaker as separation increases.	Follows inverse square law, so that the field becomes exponentially weaker as separation increases.

Magnetic field strength uses the symbol **B** in formulas, and is measured in **Teslas** (**T**).

- Some examples of magnetic field strength are...
  - Earth's = 5 x 10^{-5} T
  - Small Fridge Magnet = 0.01 T
  - Magnet in school lab = 2 T
  - Very strong lab magnet = 10 T
  - Surface of Neutron Star = 10^{8} T
- The magnitude is defined in terms of the torque ("twisting force") exerted on a compass needle when it makes a certain angle with the magnetic field.

    - We will use this vague definition for now, but a more precise definition will develop when we start looking at the math behind this stuff.
- The terms "**magnetic flux density**" and "**magnetic induction**" are sometimes used for **B**, rather than the term "**magnetic field**."

To draw magnetic field lines, follow these rules:

1. The field lines point in the direction a compass would point if placed in the field (we use it in a way similar to the use of test charges for electric fields). This means that **the magnetic field points away from north and towards south**.
2. The density of the field lines is related to the strength of the magnetic field.
3. At any point, the direction of the magnetic field is along a tangent line drawn on the magnetic field line (if it is curved).

When you are drawing the magnetic field, you can label it as B , especially if there are other things being shown in the diagram.

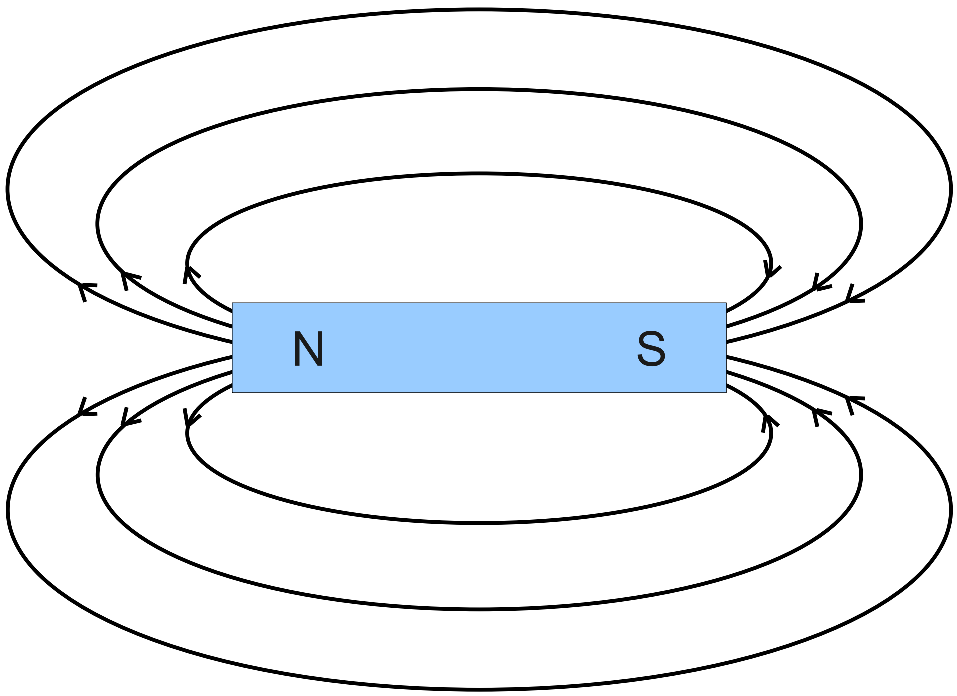

Illustration 1: Magnetic field around a magnet.

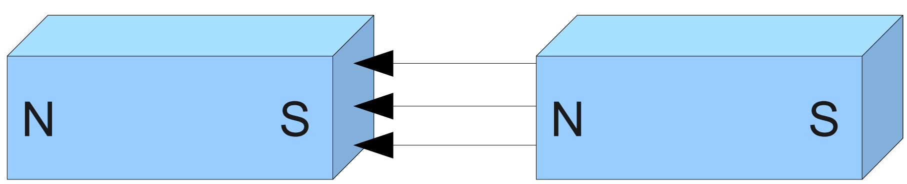

Illustration 2: Magnetic field between two magnets. Note: there would be a slight curvature of the magnetic field near the top and bottom.

William Gilbert was the first person to truly show that the Earth behaved like a giant magnet.

- Before this time, it was believed that there was something like a magnet sitting up in space up near the north and south poles of the Earth.
- Gilbert's experiments with a magnetic sphere showed him that the Earth itself must have a magnetic field of its own to have the effect on compasses that he observed.
- The earth's magnetic poles are shown in Illustration 3.
  - First, notice that the poles are reversed when you compare **geographic** and **magnetic** poles.
    - At the **north geographic** pole where Santa lives you will find the Earth's **south magnetic** pole.
- Remember how we defined the north end of a magnet... we said it points towards **geographic north** on the earth.
  - But that must mean that there is a **south magnetic** pole up there, since south attracts north.

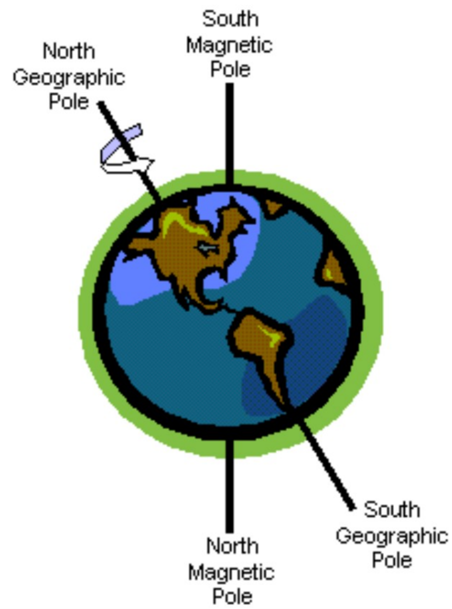

Illustration 3: Earth's magnetic and geographic poles.

Also notice that the **magnetic** poles do not line up with the **geographic** poles.

- The **geographic** poles are based on the axis that the earth spins around.
- The **magnetic** poles are based on where the poles of earth's "magnet" are found.
- The magnetic south pole is in northern Canada, about 1500 km from the geographic north pole.
  - This must be taken into account when using a compass.
  - The angular difference between **magnetic** south and true **geographical** north is called the **magnetic declination**. In Canada it's about 0° to 20°, depending on location.

Did you know?

Earth's magnetic field is actually weakening and moving. Don't worry, though. Nothing like stuff in the movie "The Core" is going to happen. Earth's magnetic field has weakened, disappeared, and reversed hundreds of times in the history of the planet. Also, the movement of the poles is not as important anymore, since the use of GPS is becoming much more common. If it's movement continues, the south magnetic pole will be in northern Russia