Domain Theory and Earth's Magnetic Field

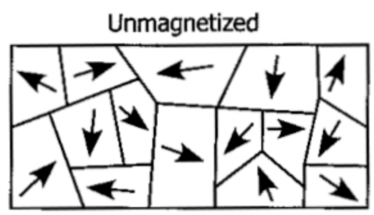
Some materials are not normally magnetic, but can become magnetized under certain circumstances. Such materials are called **ferromagnetic**. Ferromagnetic materials are strongly attracted to magnets, and are commonly referred to as magnetic substances.

Some alloys, such as alnico (aluminum, nickel, cobalt, and iron) or neodymium can form extraordinarily strong magnets. Some are able to support weights thousands of times greater than the weight of the magnet itself.

Why ferromagnetic materials have such magnetic properties can be explained by the **Domain Theory of Magnetism**. This theory states that:

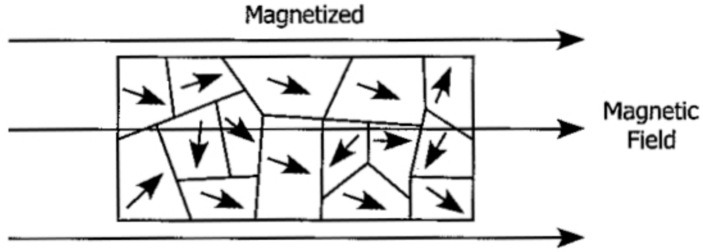
- Ferromagnetic materials are composed of a large number of tiny regions called **magnetic domains**.
- Each domain behaves like a tiny bar magnet, with its own north and south poles.

When a ferromagnetic material is in an unmagnetized state, its domains are oriented randomly, so their magnetic fields mostly cancel out.



If an unmagnetized ferromagnetic material is placed in a strong enough magnetic field, some domains will rotate to align with the external field. The net result is that many of the domains are aligned to the external field, and so they don't cancel out. This results in the material behaving like a magnet.

When the external field is removed, the orientation may remain for a long time (we call these materials **magnetically hard**), or may disappear almost immediately (we call these materials **magnetically soft**). Permanent magnets are made out of magnetically hard materials that tend to maintain the alignment of their domains almost indefinitely.



Many observed behaviors of magnets can be explained using domain theory:

1. When a bar magnet is broken in two, each half becomes a smaller magnet with its own north and south poles. This is because the domains in the halves are still aligned as they were in the original magnet. The halves are, therefore, magnetic also.

2. Materials that lose their magnetism easily are called **temporary magnets**. These are used in things like electromagnets designed to lift ferromagnetic materials (like the crane at an auto-wrecker).

3. Materials that remain magnetized for a long time are called permanent magnets. These are used in many things, including door catches in refrigerators. Impurities in the alloys help to lock the domains and prevent them from moving out of alignment.

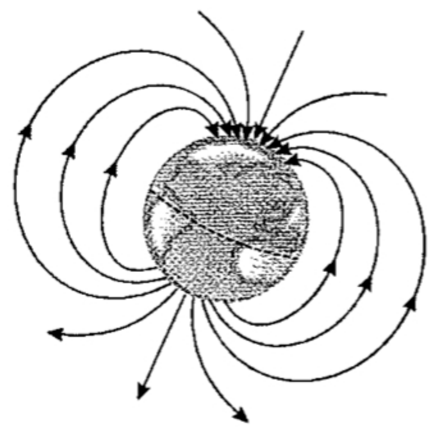
4. Heating or dropping a magnet may cause it to lose its magnetization. The domains in the material are jostled by the impact (or the increased atomic motion) and become scrambled. This can cause them to become randomly oriented, resulting in an unmagnetized state.

5. A very strong magnetic field can reverse the polarity of a magnet (switch the poles) by causing the domains to reverse direction.

Earth's Magnetic Field

Compasses work because Earth itself acts like a magnet. It has been theorized that Earth's magnetic field is similar to that of a large bar magnet, with its south pole in the northern hemisphere (which is why the north pole of a compass points that way).

Earth's magnetic field is shown in the diagram to the right.



It should be noted that the geographic poles of Earth are not at the same location as the magnetic poles. The geographic poles are the points about which Earth rotates each day, and are the points that define north and south.

The south magnetic pole (which is where the north pole of a compass points) is actually about 1500 km away from the geographic north pole. The position of the magnetic south pole moves about $40\ km/year$.

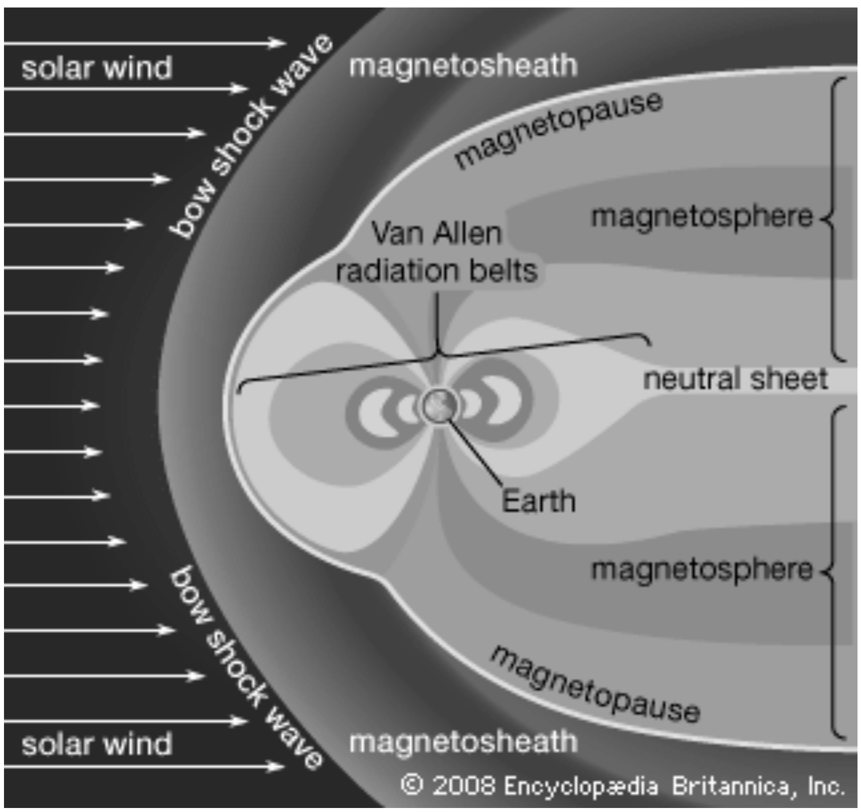
Magnetic declination is a measure of the angular difference between true north and the direction that a compass points. It varies from $0°$ to about $25°$ for most of Canada. That means, for example, that a compass needle in Victoria, BC points about $18°$ east of true north.

Earth's magnetic field is three dimensional, with both a vertical and a horizontal component. A compass reveals only the horizontal component. The angle between Earth's magnetic field and the horizontal is called the **magnetic inclination**, and is measured with a magnetic dipping needle.

Near the equator, Earth's magnetic field is nearly parallel to Earth's surface, and the angle of inclination is close to $0°$. At the magnetic poles, the field lines are directed almost straight down into the Earth, and the angle of inclination is $90°$.

The Magnetosphere and the Auroras

The **magnetosphere** is a region of the upper atmosphere beyond approximately $200\ km$ in which the motion of charged particles from space is governed by the magnetic field of Earth. On the side facing away from the sun, our magnetosphere extends approximately $57000\ km$ beyond Earth's surface. The elongated shape results from the **solar wind**. The solar wind consists mainly of protons and electrons emitted by the sun, which compresses the magnetosphere on the side closest to the sun and "blows it away" from Earth on the other side.



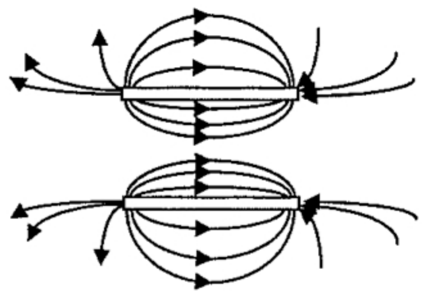
Auroras, commonly called the northern or southern lights, are caused by high energy particles from the solar wind that are trapped in the Van Allen belts of Earth's magnetic field. The Van Allen belts are regions of intense radiation within the magnetosphere.

As the particles oscillate along the magnetic field lines, they enter the atmosphere near the north and south magnetic poles. Energetic electrons collide with oxygen and nitrogen molecules in the atmosphere. These collisions excite the molecules. When they escape from their excited states, they emit the light we see in the auroras. Green light is emitted by oxygen, and pink light by nitrogen.

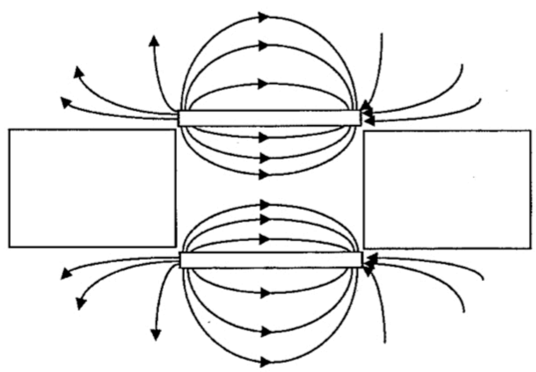
Magnetic Fields Worksheet

1. The following diagram shows two bar magnets near each other. Part of the magnetic field lines is shown.

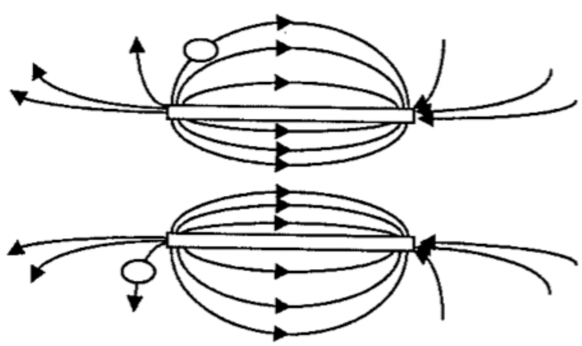
   a) from the direction in which the field lines are drawn, indicate which poles are located at each end of the bar magnet.



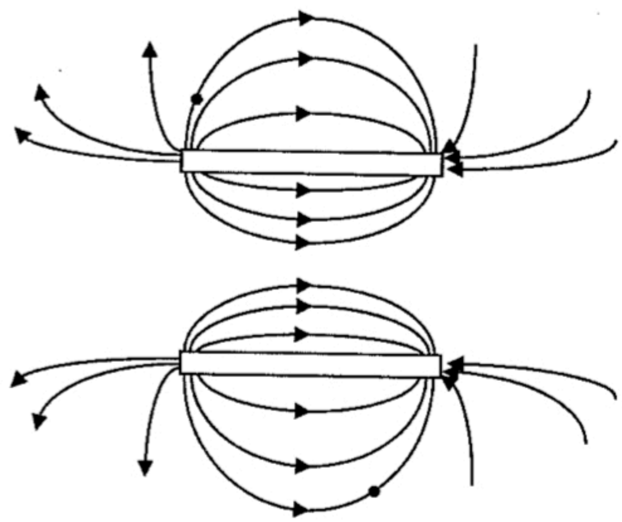
   b) The following diagram shows two rectangular regions. Add additional field lines in these areas to show how they would interact with each other.



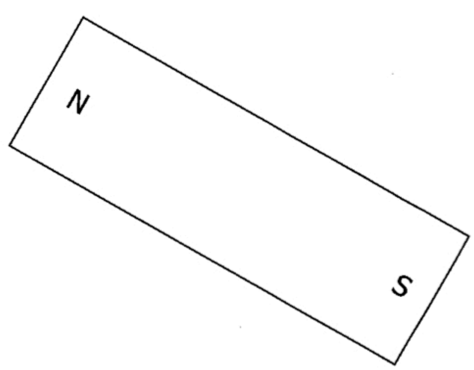
   c) The diagram below shows two compasses placed in the magnetic field of this combination of magnets. Indicate the direction in which the compass needle would point at these locations.



d) The diagram below shows two solid circles. From these circles, draw possible magnetic field vectors. In your drawing, draw one vector longer than the other, indicating which location has the stronger magnetic field.



2. Draw the magnetic field around the following bar magnet. Include eight lines in the diagram.



3. Draw the magnetic field around a horseshoe magnet.