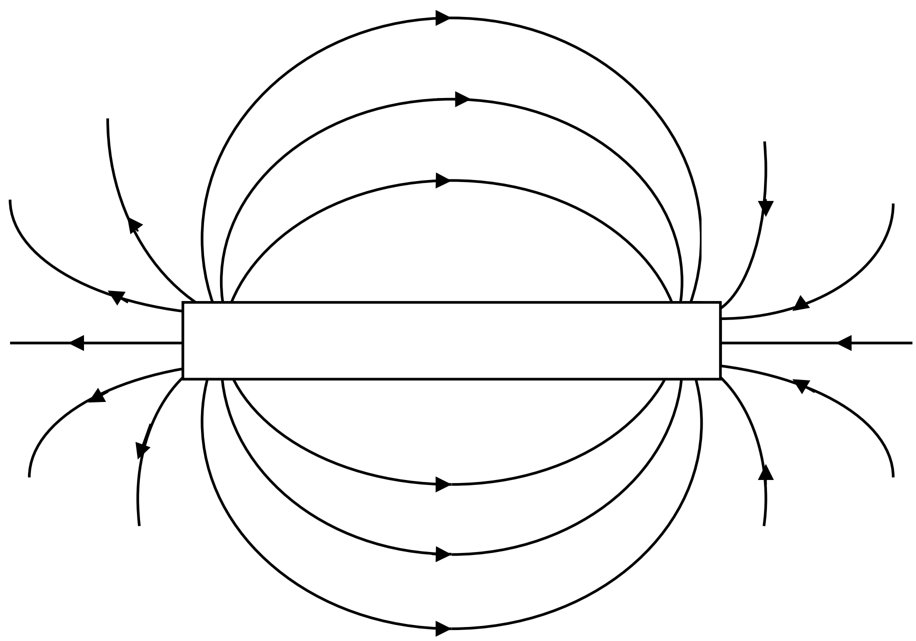
Magnetic Fields and Lines of Force

Similar to gravitational and electric fields, a *magnetic field* is a region in space where the effects of magnetic force can be felt. And, similar to electric fields, lines of force can be used to represent any magnetic field. These lines take the direction of the north pole of a compass needle at any specified location.

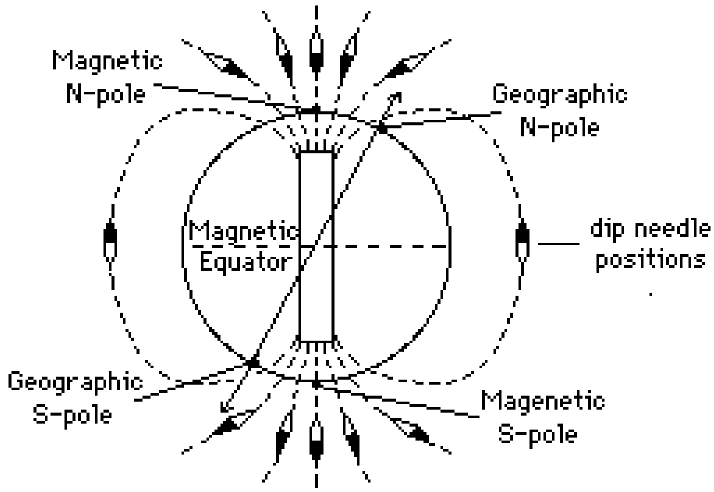


Even without labeling, it is easy to tell that the left side is the north pole of the magnet. Any compass placed close to this magnet will point to its south (right) end.

Also note that the field lines don't cross, and are more densely crowded at each pole, indicating stronger magnetism at both ends, where the poles are located.

But hold on; if the north poles of magnets, as well as compass needles (which are also north poles) seek and point to the south poles of other magnets, then why do they point to the Earth's magnetic north pole? Because, in reality, Earth's north magnetic pole is really a south pole! (or, all the magnets in the world are mislabeled)

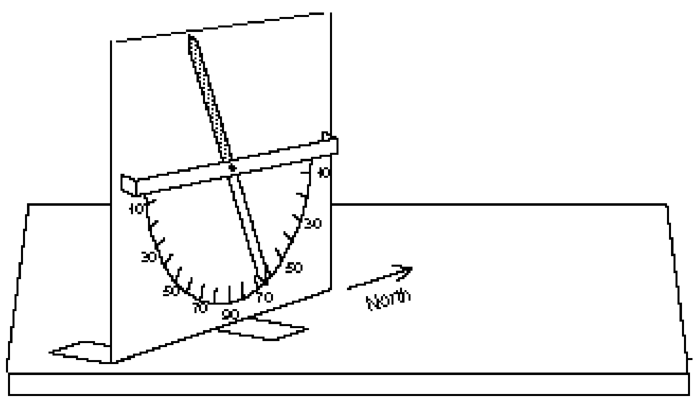
Consider Earth's magnetic field once again.



A three-dimensional compass will not simply point towards magnetic North; it will also plunge at some angle relative to horizontal:

- 90° down at the North pole;
- 90° up at the South pole;
- 0° at the equator.

An example of a plunging compass needle:



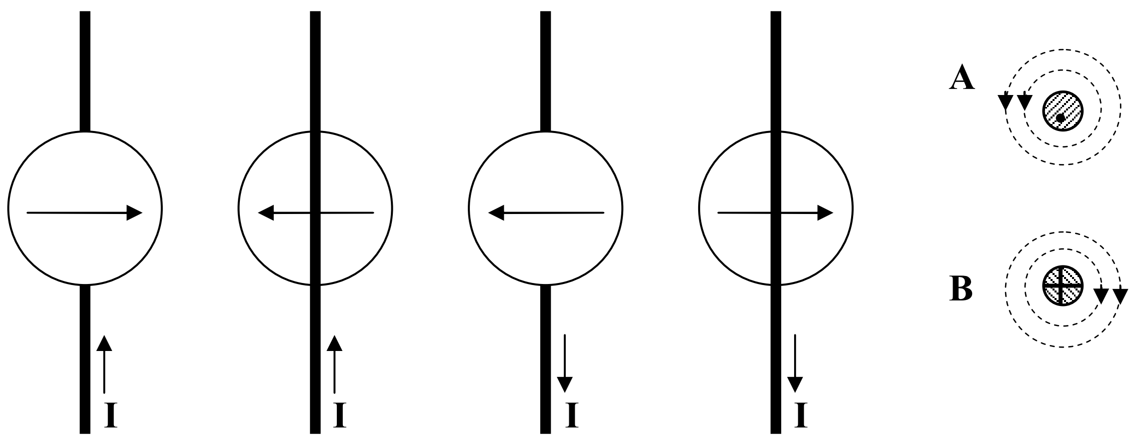
Finally, as with gravitational and electric fields, we define magnetic field as a *vector*, with symbol '**B**'. Some points to remember:

- the term 'magnetic field' can also be referred to as *magnetic induction* or *magnetic flux density.*
- magnetic fields are usually measured in units called **Tesla** (**T**).
- the direction of each field line is determined by a compass, from north-to-south *outside* a magnet and south-to-north *inside*.

<u>The Magnetic Field around a Current-Carrying Wire</u>
In 1820, Hans Christian Oersted discovered that an electric current also produces magnetism. He found that a compass placed next to a wire deflects when an electric current flows through it.

The direction of electric current flow determines the direction that a compass magnet will swing when the current is turned on, which in turn can be used to determine the shape of the magnetic field (lines) around the wire.

Examine the diagram below. The four sketches on the left show current-carrying wires (in this case, **I** represents *conventional* current) and compasses alternately placed above and below the wire. Arrows in the compass show the direction of magnetic field lines due to current **I**.



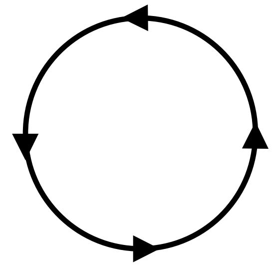
The two diagrams on the right show a view of the wires and the magnetic field lines from above. In diagram **A**, a dot in the wire indicates current flowing *out-of-page*. In diagram **B**, the cross or X indicates current flowing *into-page*. In both cases, the circular nature of the field and the lines of force around the wire are the same. However, in **A**, the field lines are *counterclockwise*, while in **B**, they're *clockwise*.

These patterns of magnetic field lines around a current-carrying wire can be predicted using a method called the *Right-Hand-Rule*:

- grasp the wire with your right hand, with thumb pointing straight out in the direction of *conventional* current; your curled fingers, wrapped around the wire, indicate direction of magnetic field lines around the wire (use <u>left</u> hand for *electric* current).

Example #1: Draw magnetic field lines for the following conventional current directions:

current into page | current out of page



Indicate the direction of **B** *inside* the loop

(see Electromagnetism Ex 1 for answer)