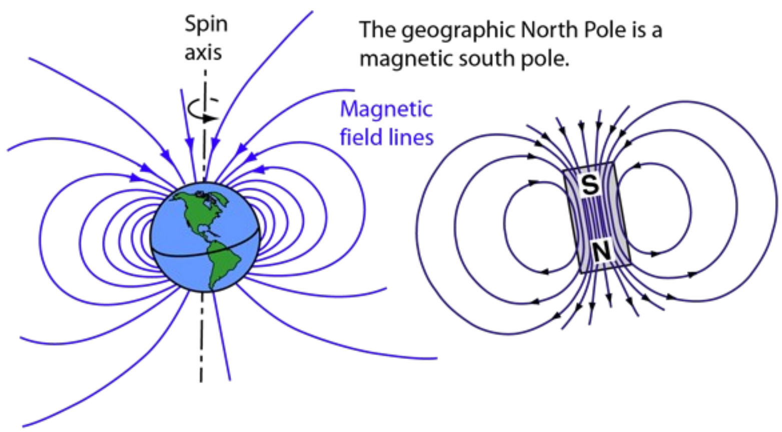
Prelab: Magnetism

Everyday thing: Magnetism what allows a compass to function, is what keeps data stored on your chip card as well as on hard drives, is how generators and motors can convert electrical energy to movement and back, is how MRI devices can map out your body.

It is physics: Magnetism (together with electricity) is one of the four fundamental forces of nature.

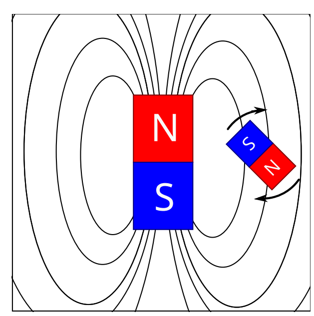
Magnetism

Here's something you know about magnets: they have two poles – usually called **North** and **South**. In fact every magnet has **exactly** two poles, which is quite different from electric charges, which are made up of single poles ("positive" or "negative" charges). The reason the magnetic poles are named North and South is of course because the Earth is also a huge magnet, where the South pole of the "magnet Earth" is close to the geographic North pole of the "spinning globe Earth".[1]



Each magnet affects other magnets by exerting a magnetic **force**, in the same way that masses affect other masses by the gravitational force or charges affect each other by the electrostatic force. An interesting way to visualize the magnetic force is to use the idea of a **magnetic field**: each magnet creates an invisible field of **magnetic field lines**, which exit the magnet at the north pole, and bend around the magnet towards the south pole, where they enter again and close a loop (see above).

If we put another small magnet into the "magnetic field" of our magnet, it will feel a **force**, where the north pole of the small magnet is pulled along each field lines and the south pole is pulled in the opposite direction of each field line. This has two effects:



- the poles of the small magnet will align with the field lines (**magnetic torque**), and

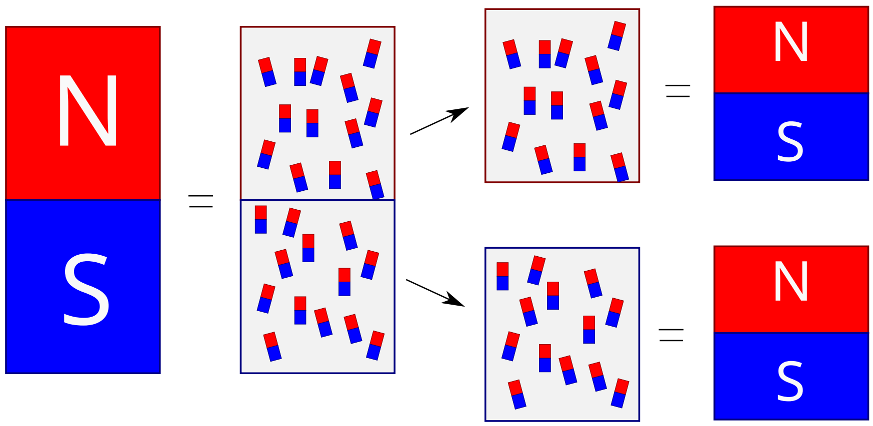
1 *Interestingly, this has not always been that way: every 100,000 years or so, the magnetic north and south pole of the Earth switch places, which is known as "geomagnetic reversal". Its effects on life on Earth, other than as a plot device for disaster movies, is largely unknown.*

- the magnet will be pulled towards where the density of field lines is larger (**magnetic force**).

If we don't let either magnet rotate and put north pole towards north pole, both the north pole and south pole are repelled by the field lines and the magnetic force pushes the two magnets apart.

The SI unit of magnetic field strength is **Tesla** (**T**), named for Serbian polymath Nikolai Tesla. A Tesla is a very large unit on the scale of everyday phenomena: the field of the earth, which easily torques a compass needle, is less than 0.0001 T. Some of the strongest magnets on Earth are electromagnets formed from superconductors which can produce a field of about 10 T.

Origin of Magnetism in Materials



Suppose we were cut a permanent magnet in half, what happens? Do we get an isolated North pole and a isolated South pole? No! It turns out that we get two smaller magnets, exactly half as strong, but each with a north and south pole.

The reason for this is that magnetism in materials is produced primarily by the **electrons**, which for reasons we don't really understand yet, are tiny magnets. We call a material a **ferromagnet**, if one can get the north poles of the electrons to more or less align and stay that way. Even though the magnetic field of a single electron is absolutely tiny, the combined effect of many small magnets pointing in the same direction produces a magnetic field so large that we can measure it.

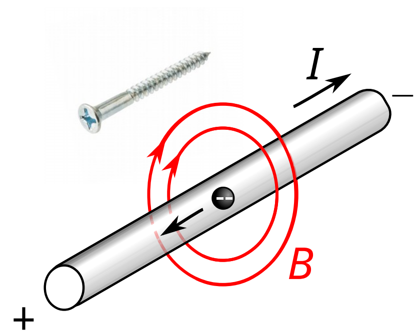
This also explains our little experiment above: by cutting our magnet in half, we just reduced the number of electrons in each half, but in each of the halfs we still got them pointing in the same directions, so we end up with two magnets of half the strength.

Electricity and Magnetism

In the 19th century, the physicists Michael Faraday, Joseph Henry and J. C. Maxwell made a startling discovery: **electricity and magnetism are linked**. This was surpising considering that these two phenomena seem to be completely unrelated to each other. More specifically, they found that

1. moving electric charges create a magnetic field, and
2. a magnetic field that is changing causes causes charges to move

Let's discuss the fact that moving charges create a magnetic field. You see an illustration of this on the right: electrons moving from – and + create **magnetic field lines** that form **circles around the electrons' path**.



To figure out which direction the magnetic field lines go, first remember that we defined electric current to be in the opposite direction to the flow of the electrons (i.e., from + to –). Picture a screw pointing in the direction of electric current. The movement of tightening the screw, clockwise in the direction of current, is exactly the direction of the magnetic field lines.

That means we can use electricity to make a magnet, and such a thing is called, you probaly guessed it, **electromagnet**. The idea here is that instead of the magnetic field lines going in circles along the wire, we would like them to "conspire" to make a strong magnetic field. The way to do this is to bend the wire into a **spiral**. Now the circles go around the loop and look very much like an ordinary magnet.