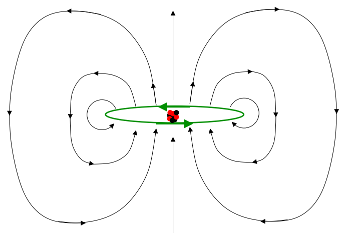
What happens when you cut a magnet in half?

August 27, 2005

Before answering this question, we need to know have an idea of how a magnet “works”. This requires us to understand how atoms create magnetic fields, and then see why we cannot just cut a magnet in half to get a north pole.

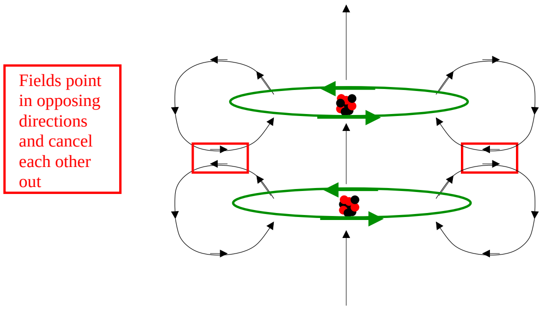
Magnetic fields from atoms

We know what the field from a loop of current looks like. In each atom we have orbiting electrons, and this is the movement of charge. A moving charge is a current, so we can model the atom as a nucleus with a loop of current. The atom and its magnetic field is shown below:



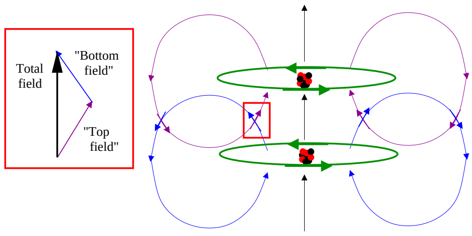
The arrows show which way the north end of a compass would point, if you could get a compass that small. The green arrow shows the direction of the net current, and the right hand rule tells us which way the field lines go. Note that the electron is a *negatively* charged particle, so it will travel in the opposite direction of the current.

Now let us look at what happens if we bring two atoms close together, with the net currents going around the same way.



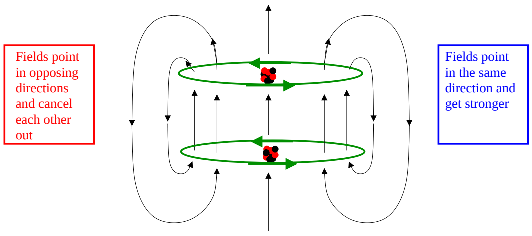
Between the two atoms the side to side fields point in opposite directions, so cancel out completely as shown in the red boxes. Strictly speaking we are looking at the field at a point, so those two arrows should be on top of one another, but for clarity I chose two field lines that are close to one another.

What happens on the inside of the orbits is slightly more complicated. Let us look at different magnetic field lines created by each atom:



We see that the field lines in the middle get stronger and go up, and the ones on the outside get stronger and go down.

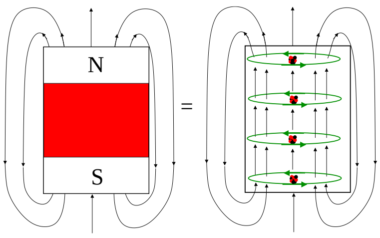
But can my diagrams possibly be right? I have drawn field lines *crossing* one another, and we know that field lines can never ever cross! Yes, the above diagram is correct but there is one subtlety. I have drawn the field for what each atom would do *by itself*. But the atoms are not by themselves – there is another atom there – and so the magnetic field is different from what each atom by itself would create. To figure out the *total* magnetic field at a point I have to look at what the field from each atom (if it was by itself) does at that point and then (vector) add these effects together. This process is called *superposition*. Doing this at every point gives the magnetic field for both the atoms together, and the field lines cannot cross as promised.



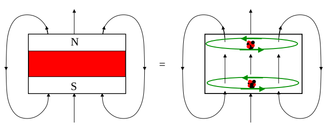
The field lines for the total field **cannot** cross.

Cutting a magnet in half

So what does a magnet look like? A magnet is simply a material that has the "currents" in the atom going around the same way. So our model of a magnet looks something like this:



Naturally magnets have many more than four atoms, but this works as a model. Now, if we cut the magnet in half and take the other half away we have



Even one atom has a "north" and a "south" pole, as the field lines never end – they just loop on one another!

Why aren't all materials magnetic?

From what I have written so far, one might expect everything to be magnetic. After all, all atoms have electrons going around them, so in effect every single atom has a current associated with it. Strictly speaking, this is correct and absolutely everything *is* magnetic, given a strong enough field. But we know that some materials are much more magnetic than others.

To get a magnetic field, we have to have a net current. Imagine helium, an atom with two electrons. Now if these electrons go around in opposite directions their magnetic fields will cancel each other out. Actually, it is a little more complicated then which way around the atom the electron goes. From chemistry you would have heard that the electron is “spin up” or “spin down”. This spin affects the magnetic field, and if the spins are pointed in the *same* direction the field gets stronger, if they are aligned in opposite directions the spin gets weaker. So helium would not be very magnetic. In fact, helium is an “anti-manget” and tries to stop any magnetic field going through it. This effect is called *diamagnetism* and is a manifestation of *Lenz's law* which we have not covered yet.

But there are a lot of atoms that have an odd number of atoms that are not very magnetic. So far we have asked whether each individual atom will be influenced by a magnetic field. The other thing you need is for the different atoms to strongly interact with one another. Otherwise one atom may decide to have a net current clockwise, and its neighbour counter-clockwise and the magnetic fields will almost cancel. The materials that have their outer electrons interact strongly are metals (they have almost “free” outer electrons) so highly magnetic materials are generally metals.