Magnetism:
From Magnetic Moments to Maxwell’s Equations

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There’s more to studying magnetism than mulling over iron magnets and their north and south poles. Magnetism is a manifestation of some very interesting laws of nature – the study of which can take you from computer chips to the cosmos.

Here’s a basic statement to get us started: magnetism arises from charged particles in motion. Let’s look at our favorite charged particle, the electron, as an example. Because of their inherit properties of spin and charge, electrons act like little magnets.

Electrons’ magnetic behavior can be observed by sending a beam of electrons through a magnetic field - like the Stern-Gerlach experiment described in the previous article (see “Having Spin and Making Stripes: Exciting Electron Behavior”). There are actually two magnetic fields that come into play – the one that is applied to the electrons, and another one that’s created by the electrons themselves.

The applied field gives some bizarre results. First, it’s important to know that magnetic fields have a vector nature; they either point up or down. When the field is pointing up, the electrons all deflect to the left, and when the field’s pointing down, they deflect to the right. (This is because they have a negative charge; positively charged particles would do the opposite.) If the field varies in space, the beam will also split into two – dividing into streams of up-spin or down-spin electrons.

So an electron acts like a magnet because of its internal motion, but what is the origin of the magnetic field that facilitates this activity? Magnetic fields are produced naturally in the glowing heat of sunspots, the molten core of the Earth, and in the rarefied gas of space. In each case electric currents are responsible for creating the field, but finding out how those currents are produced is still a challenge for researchers.
Magnetic fields can be an abstract (and sometimes overwhelming) concept. It helps if you think of a “field” as simply a way of understanding the space around us. When you study the way magnetic forces modify space, you are studying magnetic fields. When you study the way both magnetic forces and electric forces modify space, you are studying electromagnetic fields, and that’s when things get even more interesting.

Electricity and magnetism are actually manifestations of the same single phenomenon, which makes it difficult to talk about one without the other. Maxwell’s equations, developed by James Clerk Maxwell in the mid-1800s, help make sense of it all by describing the dynamo effect: moving magnets generate electric currents, and electric currents generate magnetic fields. The equations describe the relationship between electricity and magnetism, and they relate electromagnetism with light.

Studying magnetism can tangle you in a web of many other strands of science. Once you start connecting the dots between magnetism, spin, electricity and relativity you’ll be rewarded with many “light bulb” moments. Magnetism is everywhere. Whether you admire how it keeps your refrigerator decorated or how it helps keep the universe intact, exploring this mysterious force of nature is worth some mental strain.