Magnetism

The other piece of the electromagnetic puzzle is **magnetism**, which is also caused by the motion of charged particles, usually electrons in atoms. Magnetic forces originate at **magnetic poles**, north-seeking and south-seeking. All magnets have a north and a south pole. You cannot have a north pole without a south pole unlike electric charges, where you can have a positive without a negative. If you were to break a magnet in half you would have two magnets with north and south poles. This idea gives rise to the current explanation of magnetism that each atom is actually a tiny little magnet due to the motion of unpaired electrons in atoms. These types of atoms occur in iron, cobalt, and nickel and are called magnetic dipoles, basically the tiniest magnets. When large clusters of these dipoles line up with their north poles all aligned a **magnetic domain** is formed. This resulting alignment is usually due to a strong external magnetic field. If the magnetic domains in a substance are all fairly well aligned with each other the result is a **magnet**. The magnetic domains in iron, cobalt, and nickel are relatively easily aligned, as a result a magnet is usually composed a material containing one of these elements. The use of neodymium mixed one of these three magnetic metals results in a much stronger magnet. An iron nail is attracted to a magnet because its domains will align with the magnetic field of the magnet in such a way as to point the south poles of the domains towards the north pole of the magnet. If you leave a nail in a magnetic field for a long time the domains become snuggly aligned and the nail can become temporarily magnetized. Over time the nail will lose its magnetism as the domains gradually return to their natural alignment. both Striking or heating a magnet will speed up the un-aligning process by jostling or loosening the magnetic domains.

An extension of the cause of magnetism, moving charges, is a wire with an electric current flowing through it. The moving electric field creates a magnetic field around the wire according to the right hand rule (refer to class discussion). A compass, which lines up with a magnetic field will exhibit that same behavior when near a current carrying wire. Due to this phenomenon a current carrying wire can be deflected by a magnetic field. This same behavior assisted in defining the charge of electrons as they were observed in the beam of a cathode ray tube. By wrapping wire around an iron post and putting current through the wire you can produce an **electromagnet**, which you can turn on and off, as well as reverse the poles quite easily by changing the direction of the current. Electric meters, which allow the measurement of current and voltage, are based on this same deflection due to a magnetic field. In the simplest variation, a **galvanometer**, a coil of wire is placed around a steel needle on a pivot. When the current from a circuit is allowed to pass through the meter the needle is deflected based on the amount of current. This deflection can be calibrated to measure current or voltage. Most **voltmeters** and **ammeters** are of a different design today, but operate on the same basic concept.

A simple **electric motor** works due to the magnetic field produced by an electric current. Basically a magnet is used to produce a region in space with a magnetic field, a loop or coil of wire is then placed in this magnetic field. When a current flows the through the wire it causes the coil to have a magnetic field as well. The north part of the magnet's field attracts the south part of the coil's field while the same happens with the other poles. If that were all, the coil would stay stationary with the norths and souths attracting each other. However, in the motor's design are two stationary contacts, commutator, about which the two ends of the coil of wire rotate while staying in contact to allow the flow of current. As the coil rotates the direction of the current reverses so that when the south pole of the coil nears the north pole of the magnet, the coil's south pole becomes a north pole which repels from the north of the magnet. Since the coil was in motion its inertia allows it to pass by the north pole of the magnet and it is pushed around toward the south pole which attracts it, thereby keeping the coil in motion. Simply attach a shaft to the center of the wire coil and Voila! an electric motor. Electrical energy has been converted into mechanical energy. Next, we reverse the process in what is called a **generator**. Put a handle on the shaft, have your friend rotate the shaft, the coil spins in the magnetic field and voltage is produced in the wire, and we know voltage is a potential difference which causes an electric current. Now just connect a light bulb to the two ends of the wire coil and you have converted mechanical energy to electrical energy to light energy!

The last point of usefulness is that of a **transformer**. This device is composed of two separate coils of wire around a single iron core. When the powered or primary coil is switched on a magnetic field is momentarily established and an electric current is momentarily induced in the secondary coil. At this point it is about as useful as an electrostatic discharge. If, however, you turn the primary coil on-off-on-off you induce a continuous alternating current in the secondary coil. This may not seem terribly useful until you recognize that by differing the number of turns between the primary and secondary coils you can change the voltage. If the secondary has more turns than the primary, then the voltage of the secondary is greater than in the primary. The change in voltage is directly proportional to the ratio of the number of turns in each coil. The advantage of this is that electricity can be supplied from the power company at maybe 20,000 volts can be "stepped down" to the usual 120 volts at you house and then stepped up or down to meet the needs of your specific electrical devices in your house.