Dissectible Electromagnet
#4-5052

Magnets have found a million and one uses in our world and it would be hard to imagine what life would be without them. The only thing that would make a magnet more useful would be to have the ability to turn the magnetism on and off. That is exactly what electromagnets have to offer, and their uses have become indispensable.

Warning: This apparatus has been designed for use with an external power source. This power supply can be laboratory style power supply or an introduction simple battery. Voltage recommendations are between three and six volt DC.

Introduction

The ability to turn the magnet on and off with simply the use of a switch has thousands of applications in electrical and mechanical machines. The ease of construction accounts for its long use in industry. The use of magnetic cranes to lift cars is one of the first uses that comes to many people's minds, but there are many more uses that go unnoticed to most individuals. For example, electromagnets are used in vending machines and arcade games quite liberally. Due to the ability to attract certain metals, they are used in productions equipment to filter out and to separate metals from other sludge and liquids. Audio and video tape players use electromagnets to impose an electromagnetic signal on tape, which can later be used to induce a magnetic signal back into the machine for reproducing signals.

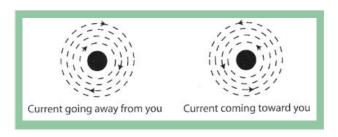An electromagnet that uses a moving yoke to slide back and forth within the core is called a solenoid. Solenoids are used to engage the starter in your car, electronic locks and security systems, electric bells, and even super powerful punches for punching out metal shapes. The electric motor is simply a revolving electric solenoid and what would this world be without an electric motor?
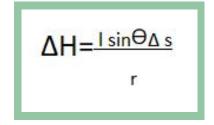
History of Electromagnetism

Electromagnetism was discovered in 1820 by Oersted. He observed that there is a presence of a magnetic field that surrounds an electrical conductor as an electric current travels through it. He also discovered that the direction of flow of the current affected the direction of the magnetic field and that it was perpendicular to the wire.

For example, take a look at the illustrations below. The circles surrounding the wire in the illustration represent the magnetic field set up by the current. In the first drawing the electrical current is traveling toward you and as you can see, the magnetic lines are traveling in a clockwise direction. In the second drawing, the electric current is traveling away from you and as you can see, the magnetic lines of force are traveling in a counterclockwise rotation. The strength of the magnetic field, created due to an electric current flow, can be calculated by Ampere using the formula below.

Current going away from you   Current coming toward you

$$\Delta H = \frac{I \sin\Theta \Delta s}{r}$$

We find using the mathematical formulas, as well as through experiments, that the intensity of the magnetic field varies inversely to the square of the distance from a wire that is creating it. We also find that by doubling the current we in turn double the strength of the magnetic field. Further study even suggests that doubling the length of the element will also double the intensity of the field.

You will find that a conductor with current traveling through it will experience a force acting on it when this conductor is located within a magnetic field. This principle is used in many practical applications such as voltmeters, ammeters, galvanometers, switches, etc. By using what you have just learned you should also reason that the direction of this force will be determined by the direction of the flow of both the current in the conductor as well as the current traveling through through the coil.

The illustration to the right depicts a simple form of a galvanometer. The coil in the middle lies between two permanent magnets.
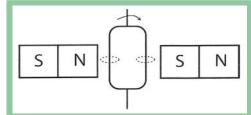

If you take a look at your Dissectible Electromagnet you will see that it is very simply constructed. There are no moving parts except for the nuts on the binding post for connecting your power source.
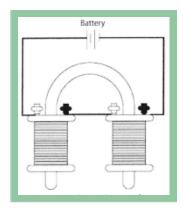
The core on each leg of the "U" shaped bolt consists of many turns of coated copper wire. The coating prevents jumping across the wire and thus creating a short. By coating the wire, the current only has one path to travel and that is along the length of the wire.
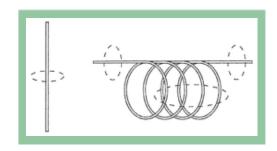

The core itself is a solid steel rod that has been bent in the shape of a "U". With the coils slipped over the bolt legs, all that is necessary to power up the electromagnet is to apply power to the binding post of the coils. See the illustration to the right of connecting procedures.
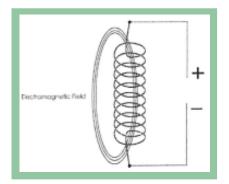
To operate the unit, turn on the power and bring the legs close to something metal such as straight pins, tack, steel paper clips, etc. You will see that these pieces of metal are drawn toward the electromagnet. Turn off the power or unhook the connecting wires. Notice that the metal samples fall away from the electromagnet. Repeat this procedure with various other metal and non-metal objects.

As current flows through the coil, a magnetic field is set up that either is attracted to or repelled by the permanent magnet, or depending on the direction of current flow. A needle attached to the coil will indicate

the amount of movement of the coil, then, the strength of the magnetic field can be determined.

Warning: Maximum voltage suggested for this unit is six volt DC. Higher voltage can result in shock or damage to the unit.

Other Experiments

Besides measuring the amount of weight that you can lift with the electromagnet, you can also use it to demonstrate the magnetic lines of force. For this you will need a sheet of white paper and about a table spoon of iron fillings. Have someone hold the paper parallel to the floor while someone else holds the magnet upside down and with the polished surface against the paper. You will not need the yoke for this experiment. Turn on the power and then sprinkle the top surface of the paper with the iron fillings. You will see a pattern emerge. The powdered iron gets caught in the magnetic field and so aligns itself with the magnetic lines of force. You should be able to witness how the lines of force travel out from the center of the core and back to its circumference. These lines of force are called magnetic flux.

The unit of measure for magnetic flux in SI is *weber* (Wb). This is named after the German physicist, Wilhelm Weber (1804-1891). The Greek symbol Φ is used to represent the total amount of flux that travels through a specific area. One weber is equal to 100,000,000 lines of magnetic flux. Also the number of lines of magnetic flux that pass perpendicularly through an area one square meter is referred to as the "flux density" and its symbol is "B". The unit of flux density is referred to as the *tesla* (T). This was named after the Serbian-American inventor and researcher Nikola Tesla (1856-1943). A tesla is the flux density of one weber per square meter.

If the flux over an area of "x" square meters and it has a number of lines "B" perpendicular through each square centimeter then the total flux throughout the area is $\Phi = Bx$.