

Lesson 05

Magnetism & Electromagnetism Transformers & Power Transmission DC Elementary Motors

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Magnetism. As we said some time ago, the discovery of magnetism and magnetic materials has been lost in antiquity. We know the Chinese were the first to use magnetism in a practical manner by creating the magnetic compass, but there is much in the ancient Greek writings to know that the Greeks knew of natural magnetic materials ("lodestone" or "magnetite") in the time of Aristotle.

Indeed, the word "lode" has its roots in the English word "led", and it was this "lodestone" that led sailors to safe harbor.



From those early discoveries of magnetite, which we believe were caused by lightning striking a naturally occurring iron ore, not much was done in trying to make a "better" magnet than iron until the early 1920s when we began investigating such things as cobalt chrome steel and in 1935 aluminum-nickel-copper-steel (Alnico). At this point it became quite easy to make an audio speaker, while up until this time it was a rather difficult process. In the early 1950s we came up with a way to make ferrite magnets, which were an alloy of strontium or barium with iron oxide ("rust") as the main ingredient. Ferrite magnets today are by far and away the most popular magnets.



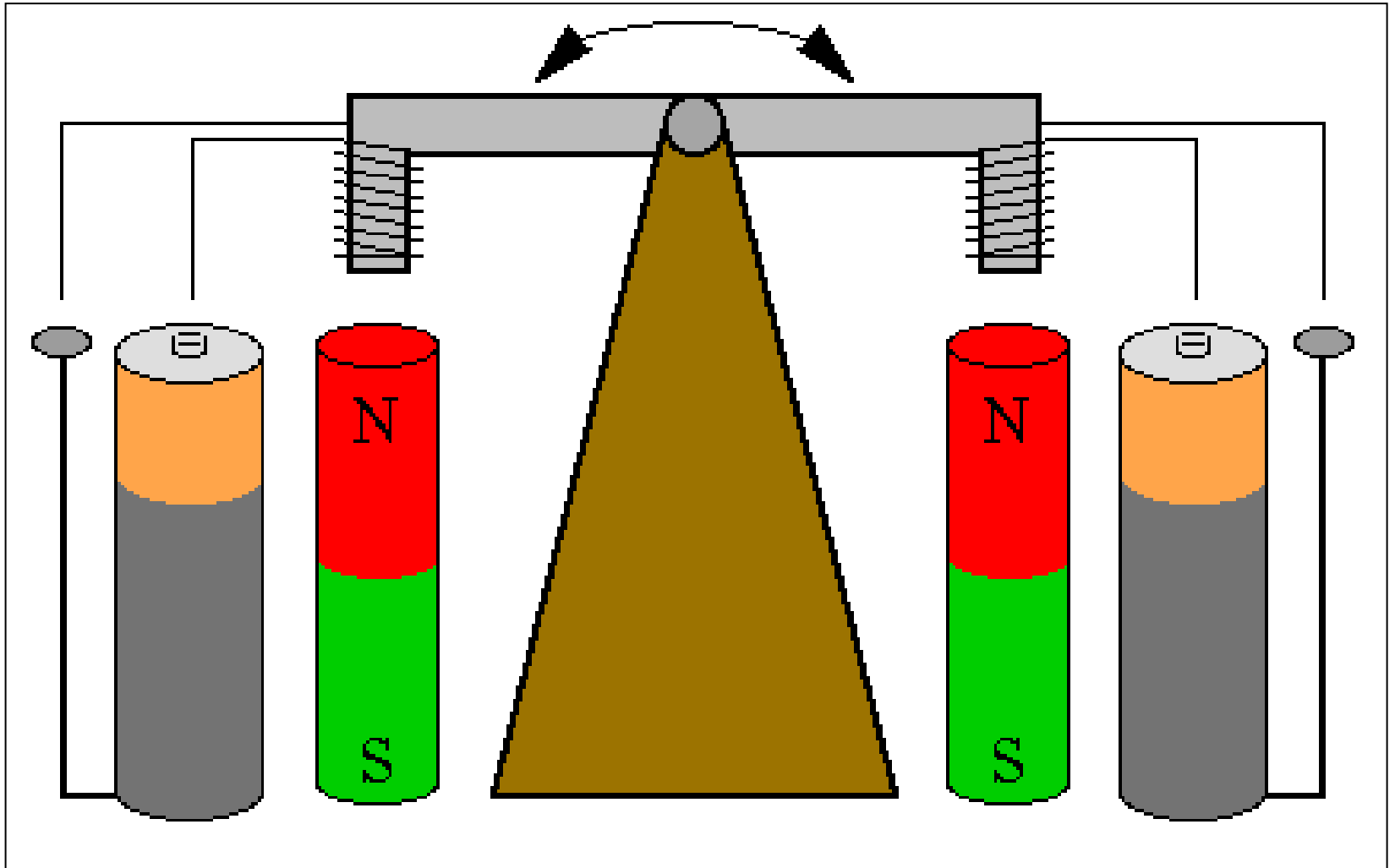
In the late 1960s, we began investigating the so called "rare earths" in the Lanthanide area of the periodic table. In particular samarium and neodymium made particularly good magnets even though they are misnamed "rare earths; they are in plentiful supply. Later in the early 1980s we found that an alloy of neodymium, iron, and boron made an even more powerful magnet -- the so-called "supermagnets" that we find in computer hard drives and other places where a small powerful magnet is required.

Electromagnetism.

In 1820, Hans Oersted noted that a wire carrying this newfangled "electric current" from a Volta pile deflected a compass placed nearby. In that same year, Ampere noted that wires carrying electric current attracted or repelled one another depending on which direction the current was flowing in each wire. In that same year, Michael Faraday explained Oersted and Ampere's observations by the invention of the concept of a "magnetic field" produced by an electric current.

Faraday goes a step further and finds that magnets can produce electricity and electricity can produce magnets, both in a wire or coil of wires adjacent to the magnet.

In 1831, Joseph Henry took the ideas and experiments of Faraday and produced the first electromagnetic motor, a little "teeter-totter" affair that proved once and for all that so long as you can keep the electricity flowing, you can produce mechanical motion.

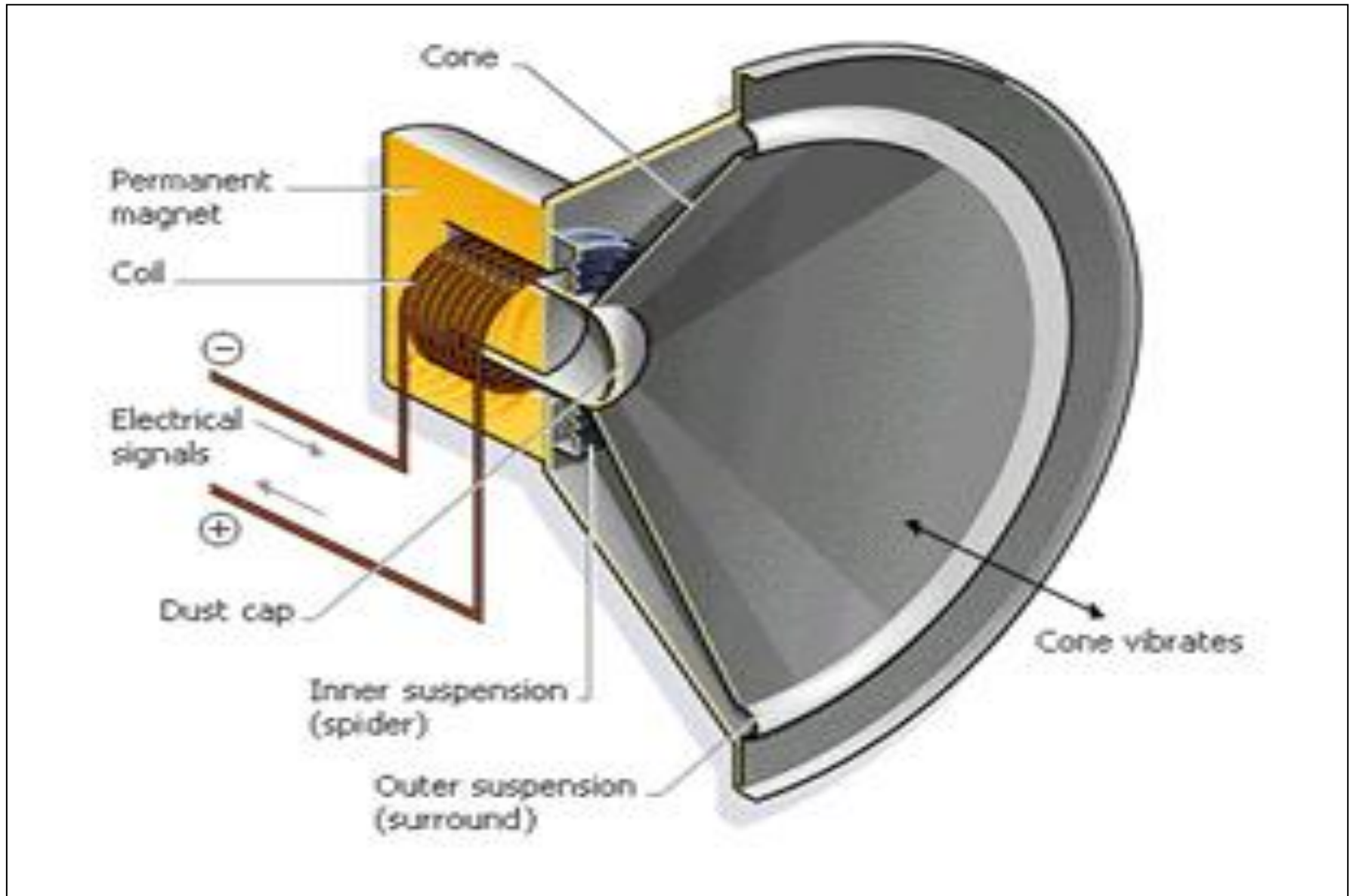


Here are some modern used for electromagnetism:

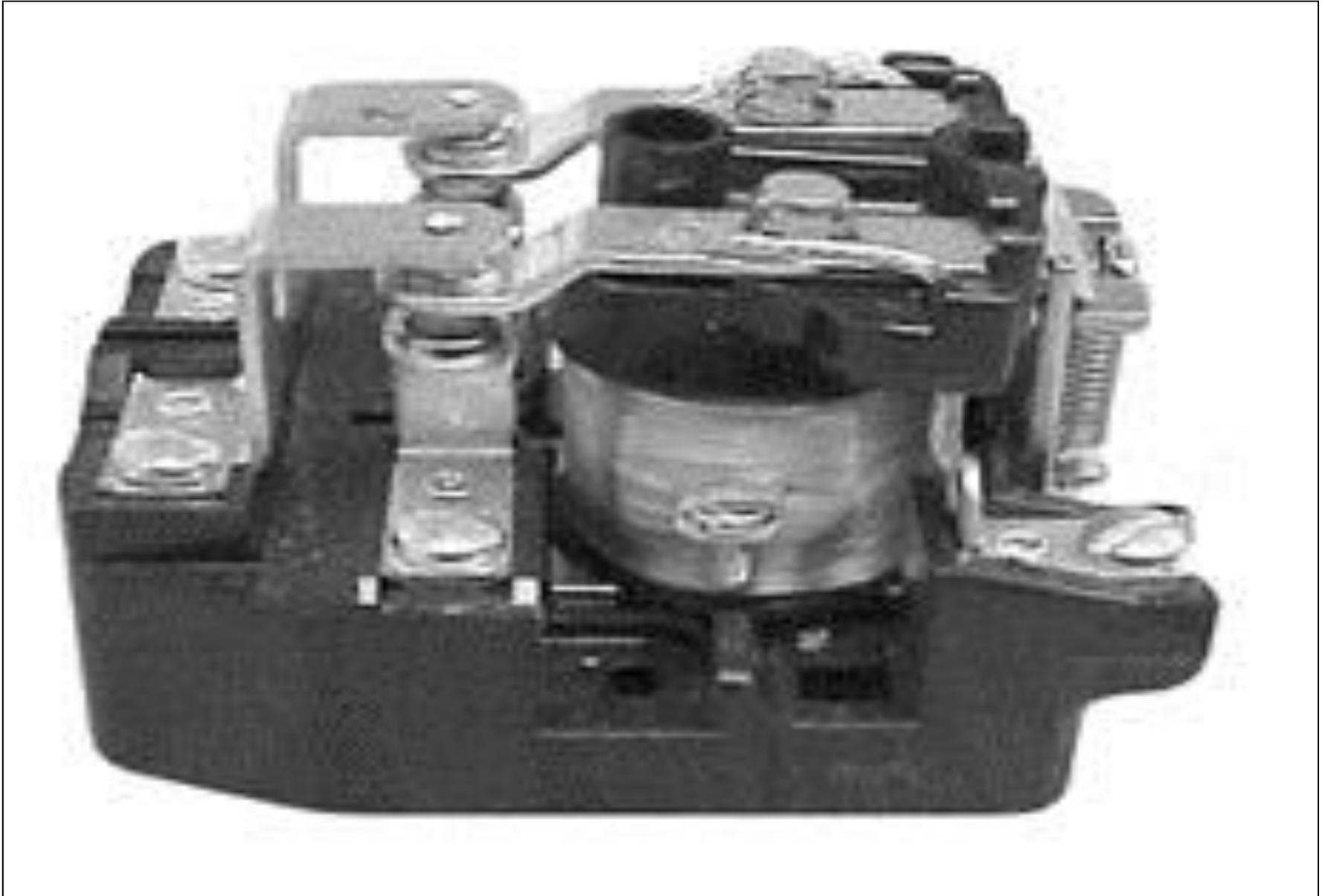
- Moving steel or magnetic materials from microounces to kilotons. A typical example would be an automobile scrapyards electromagnet mounted on a crane to move junk cars from one place to another.



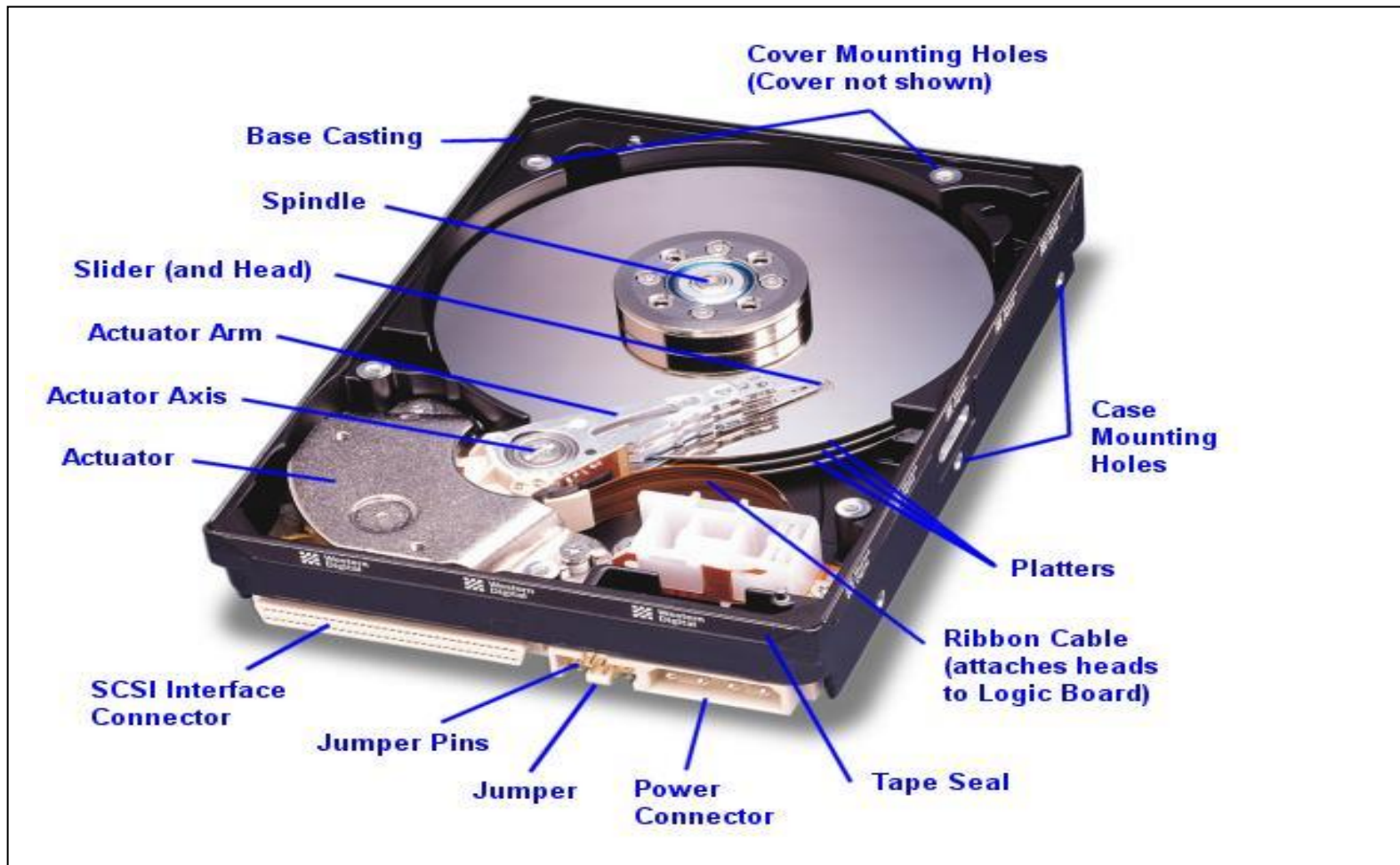
- Loudspeakers. If a moving magnet or a moving coil can induce a voltage into the coil, then a voltage on a coil with a magnetic core will move the coil. Attaching a large cone to the loudspeaker will cause the voltage (if it is audio) to make sound.



- While solid state (i.e. transistors) are making great inroads into switching electrical circuits, the venerable RELAY is still in wide usage.

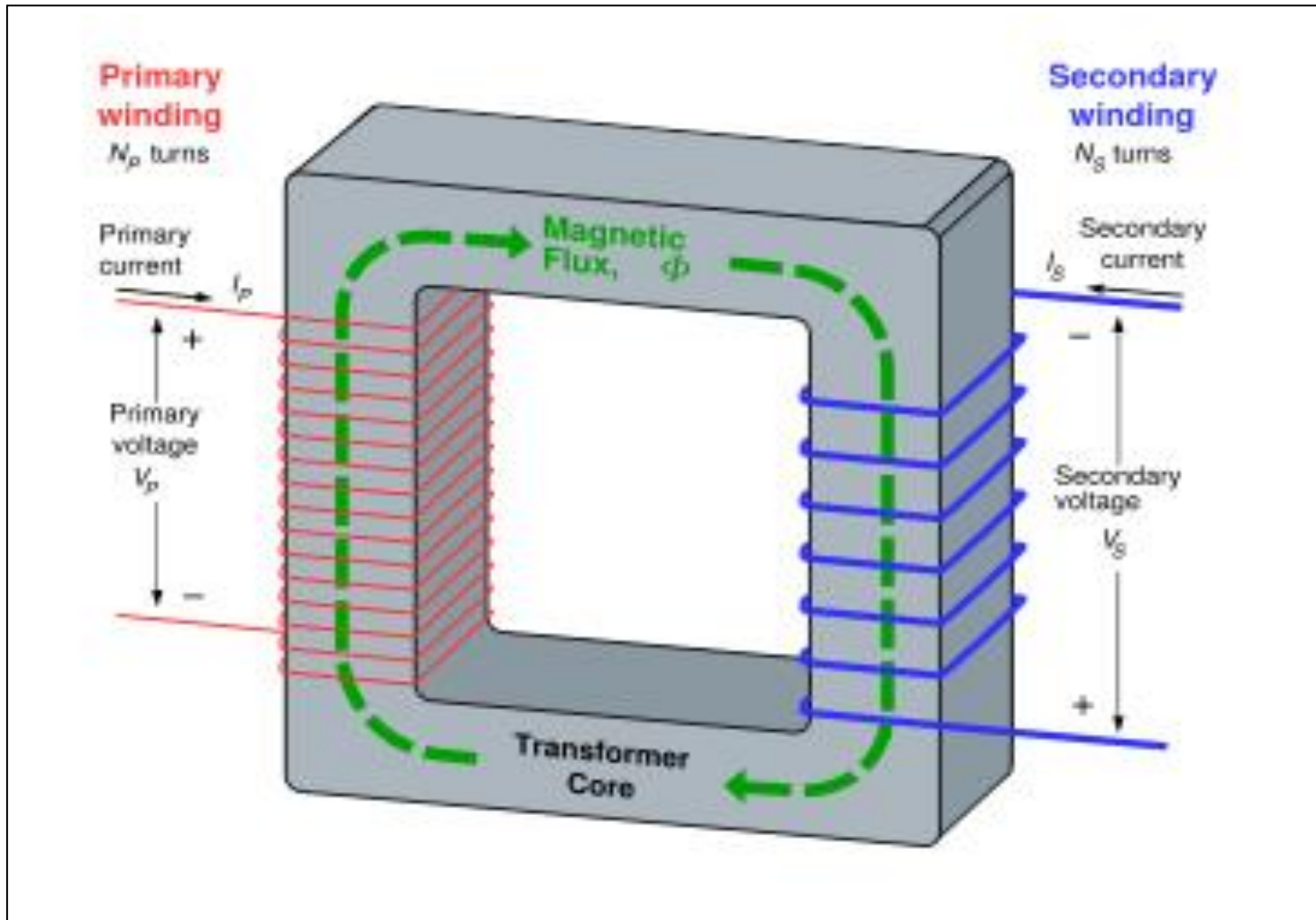


- Last, but certainly not least, is the phenomenon of small particles of ferrite bound to some sort of flexible or inflexible backing to be magnetized and then "read" at some later time. The very first widespread use of this technology is the venerable reel-to-reel tape recorders of the 1950s, supplanted by tape cassettes in the 1970s, floppy computer storage in the 1980s, and computer hard drives in the mid 1980s on.
- Note that CDROMs and DVDs are OPTICAL storage and not electromagnetic storage in the way we think of it.
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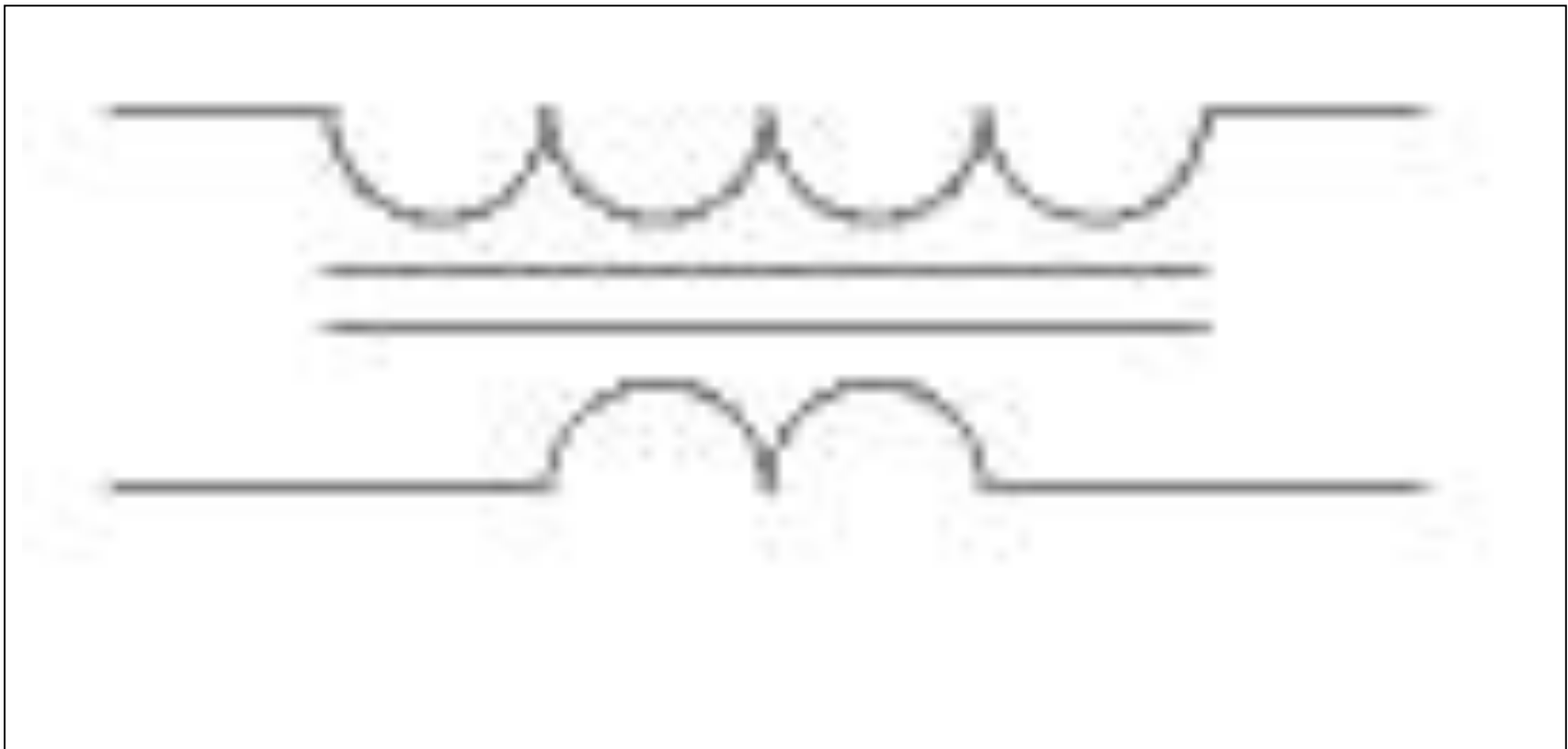
TRANSFORMERS. In 1831, Michael Faraday in England and Joseph Henry in the United States simultaneously and separately discovered the principle of MUTUAL INDUCTION. This principle says that a current in one wire induces a current in an adjacent wire without the two wires physically touching. The entire communications industry and the entire electric power industry are built on this one single principle.

Basically, a transformer consists of two coils of wire "close" to one another. We can enhance the "closeness" of one set of coils to the other by winding the coils on an iron, ferrite, or steel core such as the O-core shown here. The magnetic field is totally contained within the iron and the magnetic field passes through both the PRIMARY (red coil) and SECONDARY (blue coil) equally.



It is the **CHANGING MAGNETIC FIELD** that sets up the transformer action. For example, if you were to connect a dry cell battery to the primary winding and look at the voltage at the secondary, only at the instant that you connected the battery would there be any voltage at the secondary. Once the magnetic field established itself at one level, there would be no transfer of power from primary to secondary. This is a very important concept ... a transformer will only induce a voltage from one set of windings to the other set during the time that the magnetic field is changing. Thus, a transformer will change one AC voltage to another but will not change one DC voltage to another. (Remember the magnet in the coil? It didn't work until the magnet or the coil moved, creating a change in the magnetic field within the coil.)

The schematic symbol for a transformer with a magnetic core is simply a series of loops separated by straight or dashed lines. The straight lines in this drawing indicate an iron or steel core transformer. If the lines were dashed, it would be a ferrite core transformer, and if there were no lines at all it would be an air core transformer.



Transformers come in all shapes and sizes. The one shown here is what we commonly call a "pole pig". It drops the voltage on the transmission wires (7200 or 14400 volts) down to the 220/110 voltage required for your house or business.



These transformers are small audio and power transformers. The one in the lower right hand corner is a transformer taken out of a common "wall wart" power supply that came with a digital camera. The one in the upper right hand corner is wound on a ferrite "toroid" (TOW-royd) core and is probably from a computer switching power supply. The other two are iron/steel core transformers used in low power supplies to convert the wall voltage (110vac) down to some lower level to power transistorized equipment.

These last two iron core transformers may be a class of transformers that we call "filament transformers" that have a very interesting history. A classic filament transformer puts out either 6.3 or 12.6 volts (google the why to these voltages).



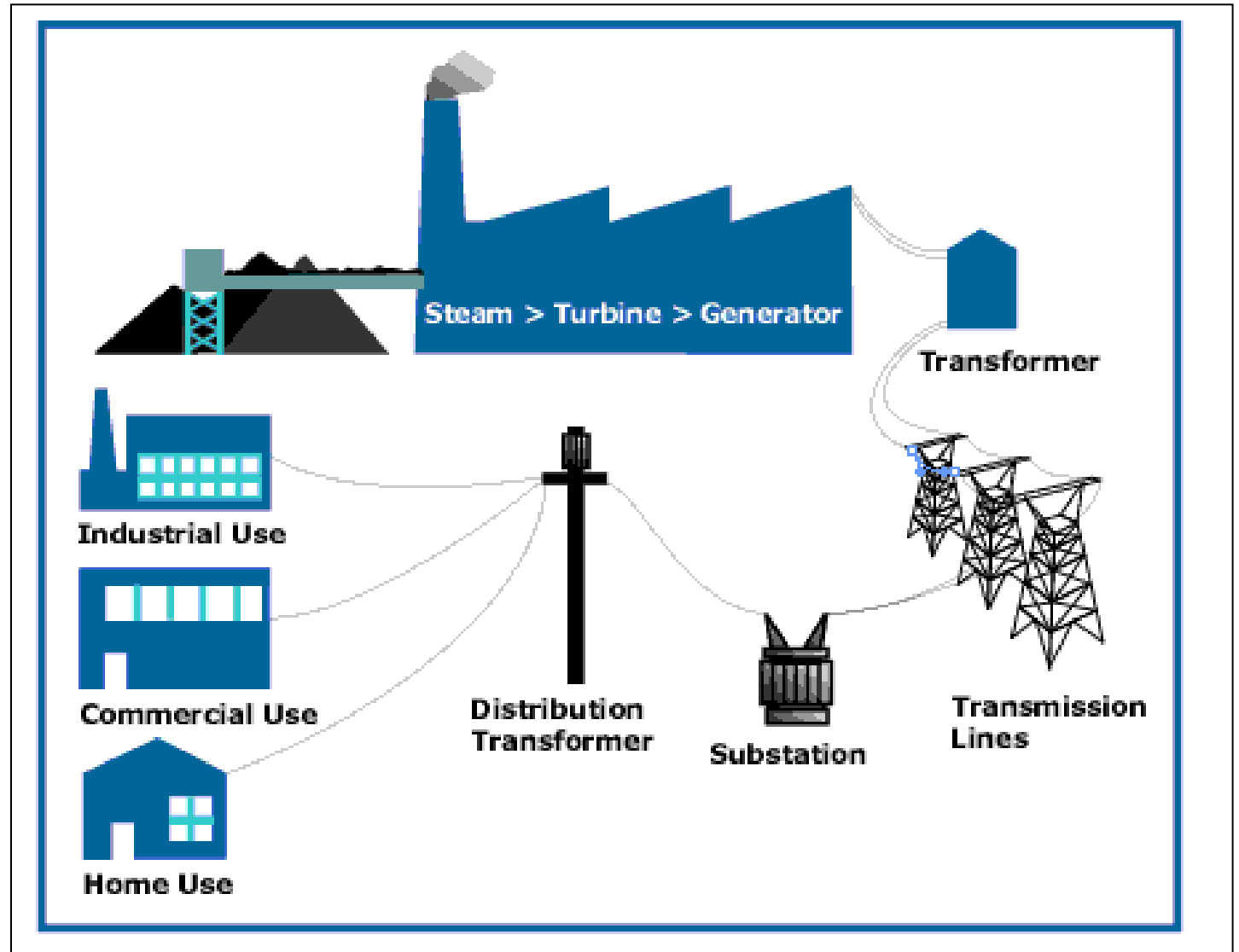
Power Generation and Transmission.

As we noted a couple of weeks ago, any method of moving a turbine wheel to move a magnet or coil will be just fine for generating electrical power.

Here we see a typical electrical generation and transmission system. "Somehow" steam is made (coal, gas, nuclear, etc.) to turn a turbine, which in turn is connected to a generator.

Typically, the generator is designed to put out about 30 kilovolts (30 kv). The transformer boosts that voltage up to somewhere between 150 and 800 kv, it is transmitted down steel or steel covered aluminum wires to a substation where it is converted back down to 7000 to 14000 volts, then to a distribution transformer ("pole pig") that drops the voltage back down to 110/220 for domestic use.

The basic principle of electrical power transmission is to use HIGH voltage at LOW current to keep the losses in the transmission wires low. Remember, Ohm told us that POWER is comprised of $\text{current}^2 * \text{resistance}$.



The power station itself is generally located out away from a populated area. In general, while people love to have the things that electricity can provide, they don't really care to have the generation plant as their next door neighbor.

Here is a photo of a coal-fired electrical power plant



The transmission towers needed to carry voltages on the order of 150-800 kv have to have some fairly heavy wire and some huge insulators to keep the voltage from jumping from the wire to the grounded tower. Here is a photo of one such transmission tower with 36" insulators between the crossarms and the wire.



Elementary DC Motors. It has been widely reported that 70% of the electric power generated in the world is used to power motors. Think about it in your own home. Refrigerator. Freezer. Heater blower. Summer fans. Saws. Drills. Computer fans. Now think about the motors used by GM on the assembly line -- like this 10,000 horsepower 60,000 pound beauty shown here.



Most of these motors are AC motors for the plain and simple reason that AC motors are generally more efficient and easier to build than DC motors. However, for our purposes, DC motors are the topic of the day.

For a very nice animation of a simple DC motor, go to this website:

<http://www.gearseds.com/curriculum/images/figures/dcmotor.swf>

or this one:

<http://www.youtube.com/watch?v=eIFUJNodXps> Some of you may wish to build THIS motor instead of the one that we show in the lab for this lesson.

The principle behind a DC motor is one of attraction and/or repulsion. The electrical energy from the power source (battery or power supply) is converted into mechanical energy by either a rotating coil or a rotating magnet. The rotating device (generally called the "armature" but strictly not always true) is alternately pulled towards a magnetic field and by reversing the current that caused the "pull" then pushed away from that field. .

