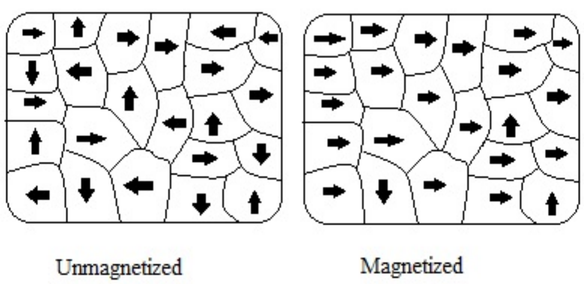
The Magic of Electricity and Magnetism: *An Interactive Overview for K-20*

By Jacob Cook

Almost all people have seen have seen or played with magnets at some point. Magnets are found everywhere, and their intriguing properties have become extensively utilized across the fields of engineering. Magnets and their basic properties have been known for centuries, but it wasn't until the 1800s when researchers and scientists discovered the true nature of magnetism. There, they learned that electricity and magnetism, two separate scientific phenomena, are interconnected via one force: the electromagnetic force.

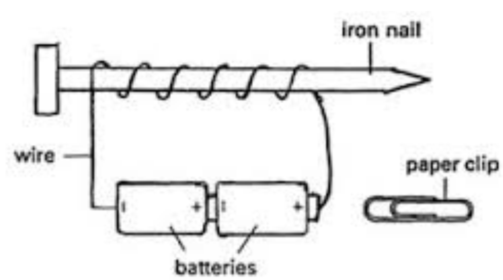
Magnets have magnetic domains, which are essentially small microscopic magnets that align in different directions. If you can align these domains (as with a permanent magnet), you can direct their individual magnetic fields into an overall field. When two magnets have their domains/fields aligned, they attract. When they do not align, they repel. Only certain metals have magnetic domains however, and many metals cannot be permanently magnetized. Magnetic fields can be created without using permanent magnets however. Instead, electricity in the form of current can induce magnetic fields. The entire purpose of this demonstration is to illustrate to the public the basics of permanent magnets, magnetic fields, electromagnetism, and electromagnetic motors.



The principle of magnetic domains illustrated [1].

In the first experiment, we will show the basics of magnetism using permanent magnets and magnetizable materials. Here, magnets will be used to deflect the magnet in a compass, which helps visualize the magnetic field. Then, permanent magnets will be used to attract other magnets. The principles of magnetic attraction and repulsion will be displayed using fridge magnets, and these fridge magnets will be placed with alternating polarities on a nail to display the repulsive effects of the magnetic field.

In the second experiment, we will take advantage of electromagnetism by coiling copper wire around a nail in a fashion that concentrates the magnetic field of current-carrying wire around a nail core. These unmagnetized nails will be used to pick up paper clips using electric current, thus displaying the magnetic effects of current in wires.



The design of a basic nail electromagnet [2].

In the third experiment, we will construct and display three kinds of motors. First, we will construct a "homopolar" motor with a balanced wire on a battery. Next, using a coil of current carrying magnet wire under an external magnetic field, we will induce rotation in the wire. Lastly, we will use a brushed motor to convey how current direction impacts motor rotation.

References

[1] "Magnetism For General Audience". People.vcu.edu. N.p., 2017. Web. 29 May 2017.

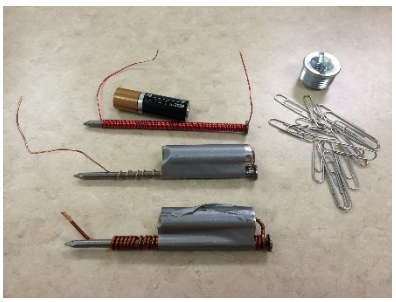
[2] "Test Papers | End Year Examination (#5): Section B". Oldschool.com.sg. N.p., 2008. Web. 29 May 2017.

Procedures:

1. Permanent Magnets and Basic Magnetic Properties

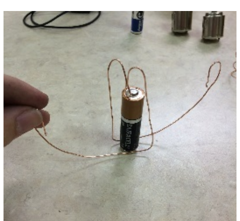
Gather the metal nuts and washers as displayed in the left photo. Then, gather the four black ferrite magnets, the six-small neodymium magnets, the pile of paper clips, and four nails. Place the ferrite magnets on a nail with alternating magnetic polarities so that they repel while staying on the nail (as displayed in the very left of the photo). Give this to the audience members to play with while you show how the different objects on the left respond to the presence of the strong neodymium magnets. Lastly, place the neodymium magnets near the compass to illustrate to the audience how magnets create a magnetic field that changes in strength and orientation depending on the placement of the neodymium magnet.

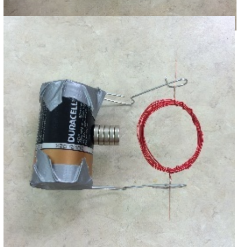
2. Electromagnets and Electromagnetism



Gather the three electromagnetic nails as shown below. Complete the circuits of the duct-taped nails to their attached battery and pick up nails to show the electromagnetic effects of electric current. Do not do this for too long, since the wiring and the battery can both become scalding hot from the high current. Next, pick up the paper-clips to show how the presence of current improves the magnetic strength of the nails. Then, complete the circuit within the red-wired nail using the given battery to pick up the heavy metal nut provided. Explain to the audience how more windings around the nail correlates to a stronger field. Lastly, open and close the circuit of one electromagnetic repeatedly nail near a compass to prove that current does induce a magnetic field in the nail.

3. Electromagnetic Motors





First, construct a homopolar motor by placing a single neodymium magnet at the base of a AA battery. Then, balance the given copper wire on the battery cathode while letting the other ends of wire rest against the magnet at the base. The wire should spin in circles around the battery.

Second, construct the basic coiled motor by taking the pre-made D battery cradle along with the red wire loop and place the loop ends within the carrying slits on the D battery. Then, place the remaining neodymium batteries near the red wiring so that an end of the magnets faces the center of the loop. This should induce spinning in the wire coil. Then, display the effects of reversing the magnet direction to convey the polarity of the electromagnetic force.

Lastly, complete a circuit containing a AA battery, alligator clips (for ease of use) and the brushed motor as seen in the photo to the right. Before completing the circuit, place the given piece of duct tape on the motor's prong to help visualize the motor's movement after completing the current. Flip the battery's orientation to reverse the direction of motion in the motor. Give this last motor to an audience member to play with.