

Dear Parent: Thank you for visiting the IEEE-USA table at the 2006 Sally Ride Festival at George Mason University. We hope that the various exhibits inspired your child to find out more about electrical engineering.

You can find instructions for building the simple electric motor exhibit and the LED flasher exhibit at the following link (near the bottom of the page, under 'EDUCATIONAL CONSTRUCTION PROJECT RESOURCES'):

http://ewh.ieee.org/r2/no_virginia/NovaGOLD/

Some more information about the motor:

Use magnet wire for the coil. Magnet wire has a thin coating of varnish as insulation, rather than a jacket of plastic like other insulated wire. Magnet wire is commonly used for the windings of motors. We used 24 gauge wire, but 22 or 26 gauge should work just as well (26 gauge is thinner, so it may be harder to work with, but the resulting coil would probably turn faster). RadioShack sells an assortment of magnet wire for \$4.99 under their part number 278-1345. This package has enough wire for lots of motors or other electromagnetism experiments.

You can also get a battery holder at RadioShack. We used two AA batteries, but C or D cells will also work. Here is a shopping list if you get these parts at RadioShack:

278-1345, magnet wire assortment (\$4.99)
270-408, holder for 2 AA batteries (\$1.49) or 270-285,
holder for 2 C batteries (\$1.59)
270-380, mini alligator clips (\$2.59), package of 12, but only 2 are needed
64-1895, rare earth super magnets (\$1.89)

You will need the alligator clips to connect the battery holder leads to the paper clips.

All of the other parts - plastic beads, paper clips, clothespins, sandpaper, and batteries - were purchased at a dollar store (such as Dollar Tree). The beads are used only to keep the coil from sliding into the paper clips, they have no other purpose. Our coil has a diameter of 1-1/8" and was wound with seven turns around a piece of PVC pipe. Any diameter between 1 and 2 inches should work. More turns will make a stronger magnetic field but also a heavier coil.

In the instructions and in our exhibit, we used two clothespins on each side just to provide more weight and stability. If you are building this project for a science fair, you may want to use something more sturdy than clothespins to hold the paper clips.

It is very important that the insulation on the wire is removed only from one side of each tail. If you hold the coil vertically, you want to have the insulation scraped off only from the bottom side of each tail. While you are taking the insulation off, make sure to keep the wire tails perfectly smooth and without kinks. The sandpaper will not reach into any kinks to remove the insulation, and the motor will not work at that point. When you are removing the insulation, you can avoid kinks by pulling the wire tail over the sandpaper towards you, instead of pushing it against the sandpaper and away from you. If you accidentally kink the wire tail, it may be best just to start over with another coil.

Because the wire insulation is clear, it is hard to distinguish the bare wire side from the insulated side. The bare wire will be shiny and may show scratches from the sandpaper, while the insulated side will be dull and smooth.

Besides removing the insulation, the hardest part of this experiment is balancing the coil so that it swings freely on the paper clips. If one side is much heavier than the other, the motor will not work.

It does not matter which way you wind the coil (clockwise or counter-clockwise). It also does not matter which direction you connect the battery. These things will only determine which way your coil will rotate, and whether it works better over the front edge or the back edge of the magnet.

This motor is a very simple and finicky mechanism, but if the coil tries to move away from the magnet when the battery is connected, you are on the right track. Sometimes the motor will start to spin by itself, but usually you will need to flick the top of the coil to get it started. Move the motor forward and backward over the magnet, and move the paper clips toward or away from the coil until you find the best spot for your motor. The best position will be with the coil centered left-to-right over the magnet, and over either the front or back of the magnet.

HOW THE MOTOR WORKS: when the coil is sitting in the paper clips so that the bare part of each tail is touching its paper clip, an electric circuit is completed. In this circuit, electric current flows from the bottom of the battery (-) into one paper clip, through the coil, and into the other paper clip and back to the top of the battery (+). When an electric current passes through a wire, a magnetic field is generated around the wire. (WARNING!! You just passed a very important fundamental law of electromagnetic theory!). The magnetic fields around each individual wire add up with each other, so that a seven-turn coil creates a magnetic field that is seven times stronger than the field around a one-turn coil. You can visualize the resulting magnetic field as if your coil was baked inside a donut: the donut is the magnetic field.

Because the coil is now in a position that the bottom is very close to the magnet, a force is created by the repulsion of each magnetic field against the other. The magnet is not going to move, so it is the coil that gets pushed away. Once the coil moves, the circuit is broken, and the magnetic field around the coil goes away. This action of making and breaking a circuit is called "commutation" and is an essential part of how a motor of this type works.

As the coil rotates, the top part of it passes close to the magnet. However, there is no interaction this time, because there is no electric circuit: the part of each wire tail that is touching the paper clips is still insulated, because you only took the insulation off of the bottom part of the tails. So the coil just continues to rotate until the bottom part comes around again. Now the bare parts of the tails touch the paper clips again, completing the electric circuit and giving the coil another push.

Here are links to some ways that other people have built this motor:

http://www.exploratorium.edu/snacks/stripped_down_motor.html

<http://home.hiwaay.net/~palmer/motor.html>

http://www.essrl.wustl.edu/~ctm2/motors/motor_pics.htm

<http://www.vk2zay.net/article.php/23>

<http://www.uen.org/Lessonplan/preview.cgi?LPid=2701>

Best of luck in your explorations, and we hope to see you again next year!