Homopolar Motor Motion

Objective

In this activity, students will discover how the Lorentz force can be used to create a homopolar motor out of just a few magnets, a battery, and copper wire. The Lorentz force is generated when electricity moves through a magnetic field. The copper wire conducts electricity from one end of the battery to the other, creating a force that causes it to spin! Once students understand how this process works, they will be able to get creative using their hands or pliers to bend the copper wire to create spinning shapes, spirals, or even a dancing figure on the top of their motor!

Materials (per student)

- 1 14-gauge piece of copper wire (various lengths depending on the desired shape)
- 1 (or more) neodymium magnet
- 1 AA battery
- Pliers or wire cutters
- Various other craft supplies to add to copper wire designs (glue guns and sticks, fabric, mini pipe cleaners, etc.)

Before You Start

For a simple design, you can shape the copper wire into a shepherd's crook, with the tip of the crook touching the positive terminal of the battery and the bottom of the wire coiling tightly around (but not touching) the magnet to which the bottom of the battery is attracted. For another simple and successful shape, bend long piece of copper wire to make a small "v" in the middle of it. Then, bend the sides out a half-inch and down to create two arms running vertically down the battery. Finally, create a coil with the ends of the arms to wrap around the battery (without making direct contact). The tip of the "v" will touch the positive terminal of the battery. You may have to adjust the copper wire by moving it around or shifting it to the side lip of the positive terminal to get it to start spinning. Remember—practice makes perfect!

How-to

1. Demonstrate the action of the simple homopolar motor to the students and asking a series of questions (you can add in your own if you'd like!):
    a. How do motors work?
    b. What do you think is causing the copper wire to spin?
    c. What direction is electricity is flowing through this homopolar motor?
2. Explain that the movement in a homopolar motor relies on something called the Lorentz force. There are a few physics terms to know to understand how the Lorentz force works.
    a. Provide a quick definition for each:
        i. A conductor is a material or device that transmits heat, electricity, or sound.

ii. Electricity is the transfer of energy resulting from the flow of charged particles (such as electrons).

iii. Electrons are negatively charged subatomic particles found in all atoms. They act as the primary carrier of electricity in solids.

iv. A magnet is an object or a device that gives off an external magnetic field.

v. An electromagnetic field is a magnetic field produced by moving electrically charged objects.

3. While other types of motors are much more complex, the electric homopolar motor was one of the earliest motors ever built. Ours uses simple materials to create a direct current that powers rotational movement. Let's look at how we can use the energy of a battery, a magnetic field, the conductivity of copper, and the Lorentz force to create a simple spinning motor!

    a. The battery is passing its stored electricity through the copper wire. Copper is an excellent conductor of electricity, passing the energy of electrons from one copper atom to another, all the way to the negative terminal of the battery.

    b. The electrical current flows from the positive terminal of the battery through the copper wire to the negative battery terminal and into the magnet. This current then flows from the magnet to the edge where the copper wire connects and travels up the copper wire back to the positive terminal of the battery to complete the circuit.

    c. The magic happens when the copper wire comes in contact with the magnets, creating an electromagnetic field and setting the stage for the Lorentz force to go to work!

    d. As the negatively-charged electrons move through the copper wire, they create their own magnetic field. The magnetic field of the electrons interacts with the magnetic field created by the magnet, creating the Lorentz force and resulting in the rotation of the copper wire you see in the motor.

4. Now, it's time to get hands-on!

    a. Provide each student with the materials they need to construct their own homopolar motor. (Students may also work as partners on one motor design if they struggle.)

    b. Explain to students that the copper wire can be bent into various shapes, such as a spinning heart, a spiral, a twirling dancer, or a unique design of their own!

    c. Before building, be sure to give students these important guidelines to building their homopolar motor shape with the copper wire:

        i. The copper wire must be touching the positive terminal.

        ii. The shape of your copper wire MUST be as balanced as possible to stay on the positive terminal of the battery.

        iii. The copper wire must make contact with the battery—looping it around is the best way.

        iv. Use caution! The wire and battery can become very hot if left spinning for a period of time.

    d. Provide students with 10–15 minutes to bend their copper wire into the shape they would like to use for their homopolar motor.

e. As students work, walk around the classroom to assist as needed and call out any especially creative designs you see! There is definitely a learning curve to this, so encourage students to keep trying and to continue to modify their design if they are struggling to get the copper wire to spin.

5. When students are finished with their homopolar motor construction, it's time to test their designs:
   a. Instruct students to get with a partner, form a small group, or form one large group.
   b. Give students time to explain their design. They may discuss why they thought their design would be successful, or if it represents a personal interest of theirs, etc. They will then setup and test their homopolar motor.
6. When the tests are complete, hold a group discussion and ask students to reflect on the designs they have seen in a group discussion:
   a. Which motors were the most successful? What made them successful?
   b. Which copper designs were the fastest or slowest and which stayed centered best? Which designs were most creative or fun to look at as they spun?
   c. What would happen if you used a wire with a material other than copper? Why is it so important to use copper for this?
   d. How would you change or refine the design of your homopolar motor to make it more successful?