Activity Title: Homopolar Motor Experiment

Recommended Grades

Grade 4, Grade 5, Grade 6, Grade 7, Grade 8, Grade 9, Grade 10, Grade 11, Grade 12

Curriculum Connections

Energy
- 4 - magnetism
- 6 - friction, uses of electricity

Computer Science
- 4 - design process

Scientific Methods
- 5 - variables (treat shape of wire as the main variable)

Junior High

Heat and Temperature - 7
Mechanical Systems - 8
Electrical Principles and Technologies - 9

High School

Energy Flow in Technological Systems - Science 10
Understanding Common Energy Conversion Systems - Science 24
Dynamics, Work/Energy - Physics 20
Electromagnetic Energy - Science 30
Forces and Fields - Physics 30

Time

Allow at least 30 minutes for bending and altering the wire as this can be rather time consuming and finicky

If copper wires have been pre-shaped by the teacher, the experiment can be done in a much shorter time frame.

Skills Focused On

• Creativity • Testing and Troubleshooting	• Observation • Critical Thinking

Materials Needed

For each motor, you will need:

- Alkaline battery
  - AA, C, or D Cell battery
  - NOT a lithium ion or rechargeable battery - these will overheat more easily
- A neodymium magnet
  - Regular magnet will NOT work - not strong enough
- Copper wire
  - Uninsulated hardwire, about 16-18 gauge. Thinner wire may not work as well, and thicker wire may be too heavy or difficult to bend.
  - Craft stores, tool stores, and online are good sources.
- Wire cutters or scissors
- (Optional) Pliers - will make bending the wire into shape easier

Optionally:

- Print copies of “Homopolar Motor - How It Works” and “Homopolar Motor - Instructions and Safety notes” documents for each student or group

Background Information

An electric motor is a machine that converts electrical energy (that we use to turn on lights, charge our phones, and use a computer) into mechanical energy, which is the sum of potential energy (the energy held by an object because of its position relative to other objects) and kinetic energy (the energy of motion). In other words, electricity becomes movement!

From a big car to a tiny electric watch, motors can be found all over the place, and they come in all shapes and sizes. Without motors, we wouldn’t have refrigerators, vacuum cleaners or washing machines, or so many other important things we use every day.

But how does a motor work anyway?

Most motors use magnets to create motion.

If you’ve ever played with magnets, you know that it has two ends, called poles. Try to put two north or two south poles together, and the magnets repel each other, resisting the motion. But if you try to put two opposite poles together, they snap right into place because of the attractive force. Opposites attract, likes repel.

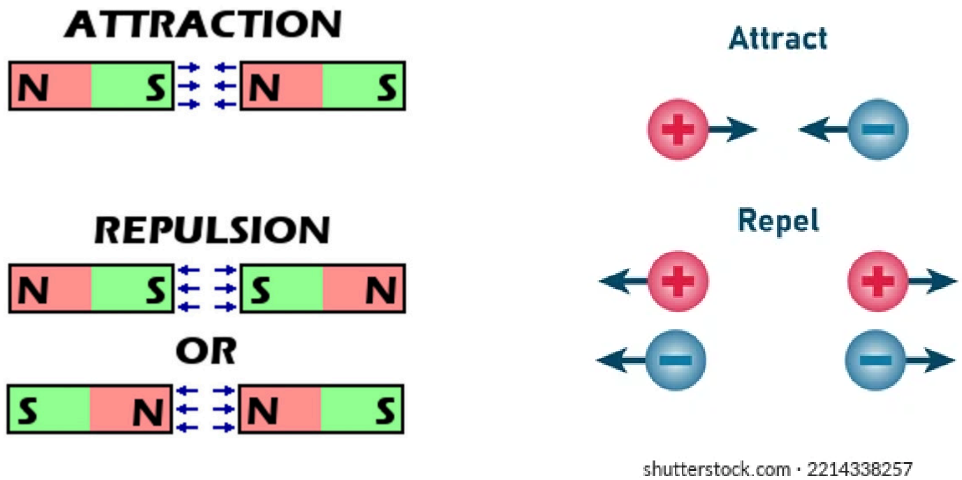


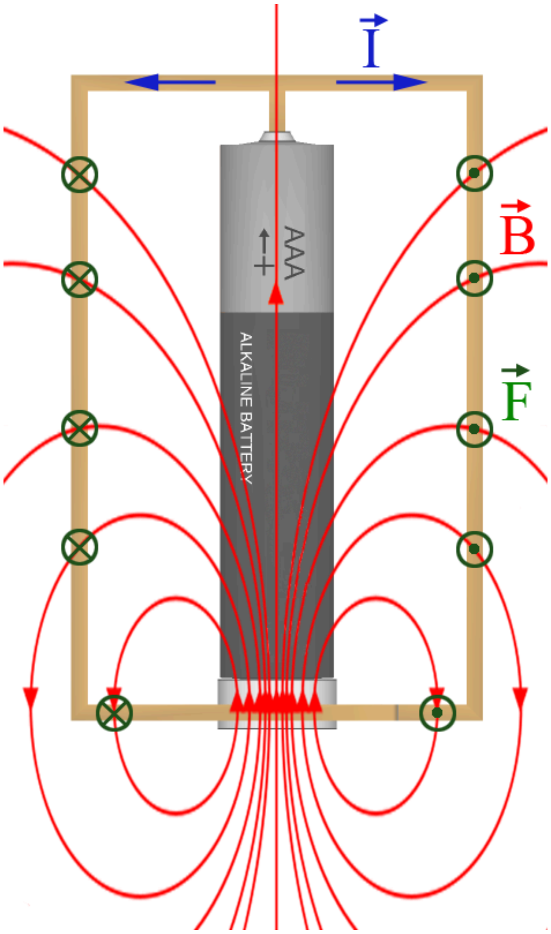
Image Source: kjmagnetics.com (left), shutterstock.com (right)

Like magnets, charges also have two types, but we call them positive and negative instead of north and south. Also like magnets, opposite charges attract and like charges repel. Inside an electric motor, electric and magnetic forces work together to create rotational motion.

The first electrical motor was created by a scientist named Michael Faraday in 1821. This experiment involves creating our own electric motor, specifically a homopolar motor!

Homopolar motors work because of the relationship between magnetism and electricity. When we connect the wire to the top end of the battery and the side of the magnet, charge starts flowing through the wire as we have completed the circuit (to learn more about circuits, check out our circuit video: https://www.youtube.com/watch?v=jToG6Fx9mEg). When an electric charge is not moving (the circuit is broken), it does not notice the magnetic field and the wire stays still. But as soon as those charges start moving through the wire, they can suddenly “feel” the magnetic force and the wire starts spinning. This force created by interacting electric and magnetic fields is called the Lorentz force.

For additional details, refer to the image and caption below. This level of detail is not necessary for elementary school students.



In the centre is a battery surrounded by a brown rectangular copper wire. The magnet is on the bottom of the battery. The blue "I" represents the electric current. The red "B" represents the magnetic field. The green "F" represents the force, which results from the interaction between the electric field and the magnetic field.

This image is a 3D representation, so the circles with green Xs represent the force going INTO the page/screen, and the circles with the green dot represent the force coming OUT of the page/screen. With the right side coming out of the page and the left side going into the page, the wire would spin like this (https://www.youtube.com/shorts/GzWDtd8D6HE).
Image credit: Wikipedia.

The copper wire starts spinning in the direction of the magnetic force – but it only works when charge is flowing through the wire. Isn't that cool?

Safety Notes

Batteries

- Do not attempt to build a motor like this using a rechargeable battery, or any battery type other than alkaline. A lithium battery, Ni-Cad batteries, or any other high energy battery will overheat more easily.

Neodymium Magnets

- Watch your fingers! These are very strong magnets that could pinch the skin on your finger quite painfully. Stick to lightweight magnets <1 oz. for this reason.
- Be careful not to let these magnets “snap” together quickly, as they can shatter!
- Keep away from small children! These magnets are dangerous if swallowed and must be surgically removed.
- These magnets are strong enough to affect electronics. Though most modern phones and computers are built differently, so they will no longer be destroyed by magnets, these could still magnetise some steel in your phone, interfering with its compass and location data. They may completely wreck older devices. To be safe, keep these magnets three feet away from tech.

Wire Cutters or Scissors

- It can be challenging to cut through the copper wire. An adult should help with this step.

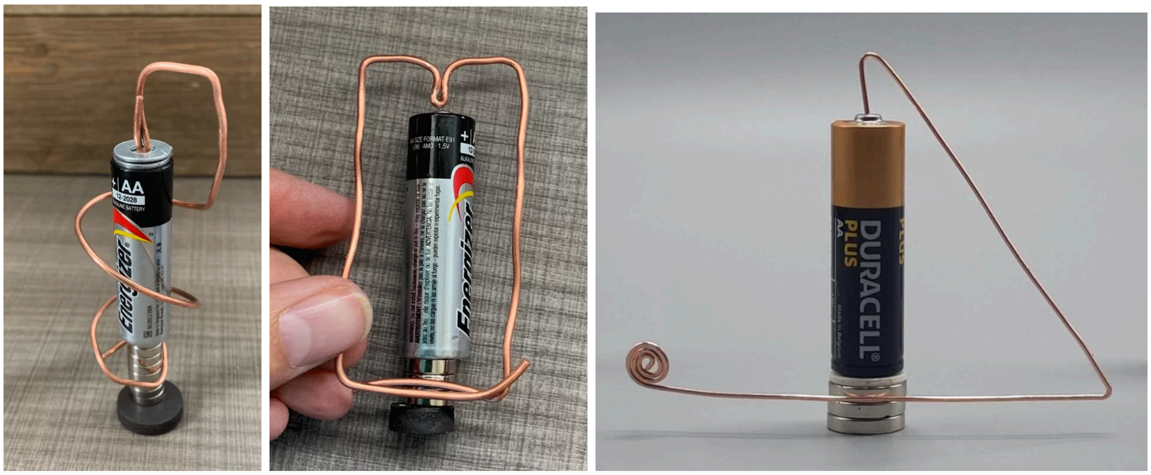
Other Notes

- Monitor your motor’s temperature. If you feel the battery or wire getting warm, stop and let it cool down. Swap it for a fresh battery, if available.
- If you want to be extra safe, wear insulated gloves.

Experimental Steps

1. First, separate your magnets by **sliding** them carefully apart. Don’t try to pull them apart – they are too strong. Teachers, younger students will need help with this.
2. Set the magnets you are not using aside, far enough that they won’t get in the way or be attracted to each other (at least 2 ft away from other magnets).
3. Place the magnet(s) you are using on the bottom of your battery. This is the flat side (negative terminal).
4. Next, it’s time to shape your wire. It can be challenging to cut through the copper wire. Teachers should help younger students with this step. There are a lot of shapes that will work.
    a. The coil shape can be made by wrapping the wire around a cylindrical object.
    b. It is okay if the wire looks lumpy or messy. The important thing is that it is a) touching both the top of the battery and the magnet, b) not dragging along the

table or touching the body of the battery too much. This will create friction which stops the wire from rotating.



Example shapes - encourage students to get creative!
Sources (left to right): Image 1, Image 2, Image 3

5. Place the wire on your battery - **one end must touch the very top of the battery AND the other end must touch the side of the magnet**. It's harder than it looks! Pliers can help. If you get frustrated, remember, science is all about trial and error. Tinker with your shape until you get the motor running!
    a. Monitor your motor's temperature. If you feel the battery or wire getting warm, stop and let it cool down. If you want to be extra safe, wear insulated gloves.

Eventually, you will use all the energy stored in the battery, the current will stop flowing, and the motor will stop. Make sure to recycle your empty batteries – don't just throw them away, as this can hurt the environment.

Discussion/Experimental Extensions

How do you think the motor works? Encourage students to make a guess before explaining the scientific principles behind it.

Want to make a better homopolar motor? Try some different designs! Which shape of wire gets the motor running the most smoothly and quickly? Which shape looks the coolest as it spins around?

What happens if you add more magnets? How about swapping a AA battery for a C or D type battery? Record and discuss your results.

Additional Resources

[Video Coming Soon] experimental video produced by Future Energy Systems - provides background information and instructions for experiment: [Video Link Coming Soon]. Learn more about Future Energy Systems (https://www.futureenergysystems.ca/) and access more learning content, including storytimes, lab tours, ask an experts and more (https://www.futureenergysystems.ca/engage/learning https://www.youtube.com/channel/UCJr8N9KyFJ6d-t36TPtUlwg).