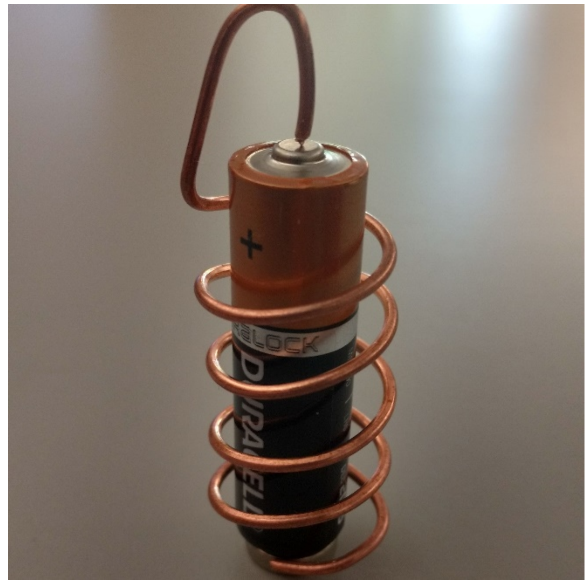
Homopolar Motor

Workshop

Participants learn the everyday science of electric motors in this fun and engaging workshop activity.



Number of Participants: 2 - 30

Audience: Middle (11 - 13) and up

Duration: 20 - 30 minutes

Difficulty: Level 2

Materials Required (per partipant):

- 16 gauge copper wire (~35 cm)
- 20 guage copper wire (~14 cm)
- AA batteries (1)
- 1 ¼” non-coated steel screws (1)
- ½” neodymium magnets (1)
- ¾” wooden dowel (~10 cm)
- Pliers/wire cutters (shared)

Setup:

1. Distribute workshop materials to the participants. Be careful with the neodymium magnets, as they can be difficult to separate and are very fragile.

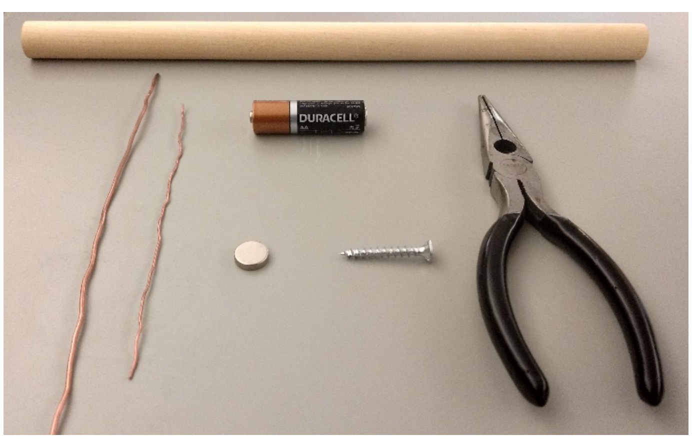


Figure 2a: Materials required for each participant.

Figure 1b: The wooden dowel has a slightly larger diameter than the battery.

Presenter Brief:

Be familiar with circuits, forces and torques, and introductory electricity and magnetism topics. The Lorentz force and related phenomena are important for this demonstration. Vector mathematics and symmetry arguments are also key components of the activity.

Vocabulary:

- Voltage – an electric potential difference which allows for charge to migrate from one body to another
- Current – the flow of an electrical charge
- Torque – a rotational force

Physics & Explanation:

Middle (ages 11-13) and general public:

Begin by introducing the materials one at a time, and remind the participants to be careful throughout the activity. Note: There are sharp points on some of the materials. Also, because of low electrical resistance of the wires, the circuit can quickly become warm or overheat.

Motors are an integral part of modern technology. In general, a motor is a device that transforms energy from one form to another. Here, electrical energy (stored in the batter) is transformed by the motor into kinetic energy (motion). Generators work in reverse: transforming kinetic energy into electrical energy.

Motors are designed to transfer electrical energy into kinetic energy.

There are many types of motors. Each design is optimized for a specific need, such as speed and torque.

Instruct the participants to first use the 20 gauge wire, magnet, screw, and battery to propose how to create a motor.

Because configuring the motor incorrectly can overheat the materials and drain the battery's charge, it is best that the participants wait until instructed to test their theories.

The answer is not obvious, especially for those who have little or no experience with circuitry.

Show participants the correct way to build the motor using the materials provided. It may be necessary to add the stipulation that the wire may not be coiled or otherwise shaped in a way that makes the wire itself move- this will be the next step.

Why does this configuration of the motor work when other similar configurations do nott? Are there any ways the motor can be configured that make it still operable, but with less power? The order of each component in the circuit is very important, so what can be concluded about how the motor works?

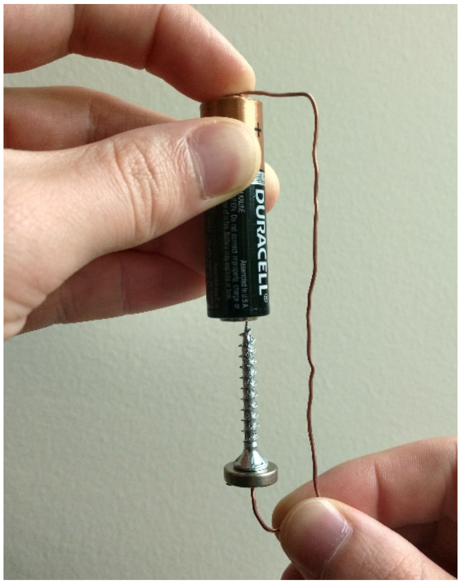


Figure 3: The assembly of a rotary arm homopolar motor.

The motor works by the interaction of the electric current produced by the battery and the magnetic field.

Introduce the thicker gauge wire as well as the dowel and ask participants to once again propose design ideas for motors using these tools. Again, the answer is not obvious, even with the knowledge accrued from the previous design.

Use the dowel to shape the coils of the wire and the pliers to shape the upper and lower connections. As long as the wire keeps contact with the magnet, the coil will turn. Note that the magnet rests underneath the negative terminal of the battery.

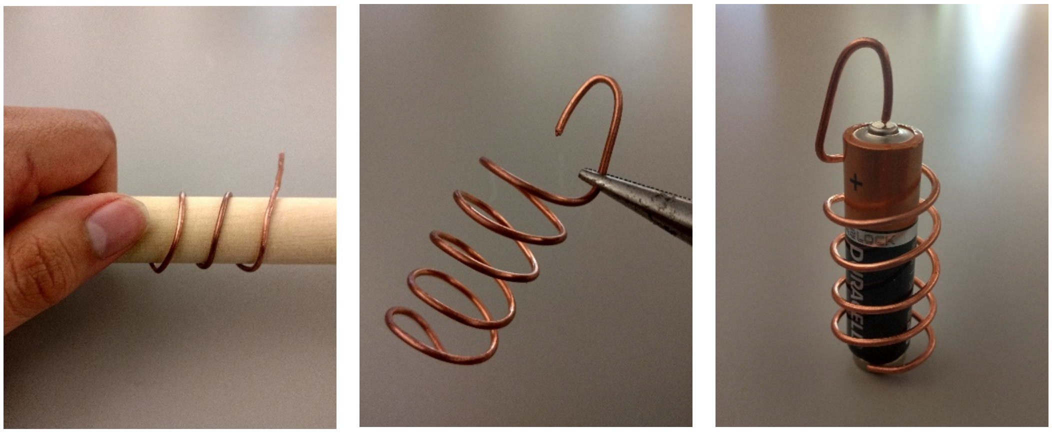


Figure 4: The setup and assembly of the rotary coil homopolar motor.

Electricity and magnetism are often talked about in similar settings, however they are not one and the same. A battery holds no inherent magnetic field, and a permanent bar magnet holds no inherent charge.

Highschool (14 +):

After completing the previous section, return to the idea of current and explain that the interaction of the magnetic field with the charge flowing through the wire creates the torque force directed off center so that the object rotates.

There is nothing physical in the motor causing the torque. The actuation of the rotating component does not require an initial kinetic motion, so the interaction must be in something that cannot be observed.

The magnetic field creates a torque on the current-carrying component of the motor through the Lorentz force.

The equation for the Lorentz force provides us with a method for determining the magnetic force on an object given a moving charge, or current, and a known magnetic field direction.

$$F_l = qv \times B$$

It is not necessary that the participants fully understand the equation, however it may be beneficial to draw attention to the cross product of the relationship between the magnetic field and the direction of current flow.

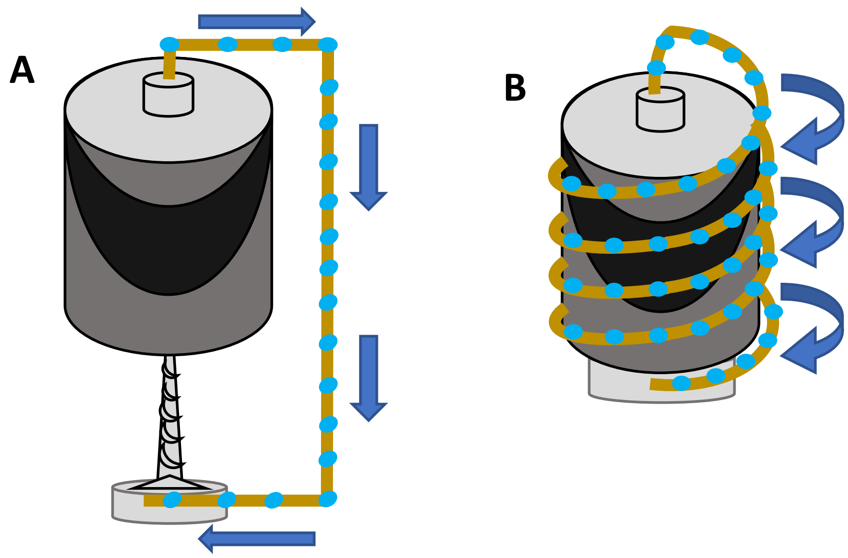


Figure 5: Diagrams representing the flow of conventional charged particles from A) the rotary arm design of the motor and B) the rotary coil design.

Additional Resources:

- Halliday, Resnick, & Walker. *Fundamentals of Physics*, 2001. (p 701 – 715)
- More configurations for homopolar motors https://www.youtube.com/watch?v=BJg4Q05R6L4

Useful Equations:

Lorentz Force	$qv \times B$

$v = velocity\ of\ the\ charged\ particle\ (m/s)$

$q = charge\ value\ of\ the\ particle\ (V)$

$B = magnetic\ field\ (T)$