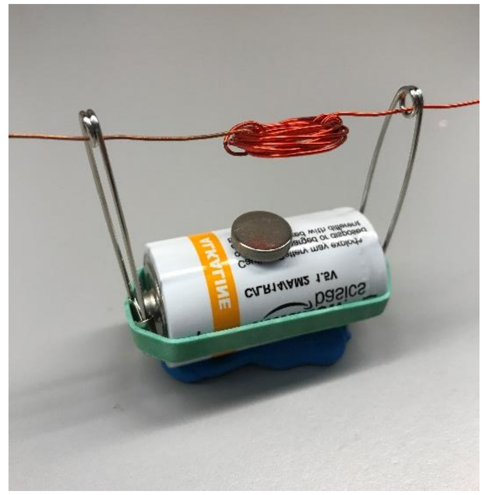
Simple Motor

Workshop

Build a simple electric motor out of everyday materials. Participants will learn about current, magnetic fields, and other physical phenomena that make motors work.



Number of Participants: 2 – 30

Audience: Middle (ages 11-13) and up

Duration: 20-30 mins

Difficulty: Level 3

Materials Required (per participant):

- One C battery
- 2 metal safety pins (large, 5” tall)
- Small magnet (neodymium or equivalent strength, ½ inch diameter)
- ~70 cm of 22 AWG magnet wire
- 1 wide rubber band
- A small piece of sandpaper (3cm x 3cm)
- Sticky putty / tack (optional)

Setup:

1. Make a 10-loop coil of magnet wire. This can be done by wrapping it around a circular object (such as an appropriately sized pen or dry erase marker). Slide it off to create a small coil with diameter of about 2 cm, leaving two ends sticking out a few inches, as in Figure 1. Participants can also do this step themselves, if age appropriate and time permits.

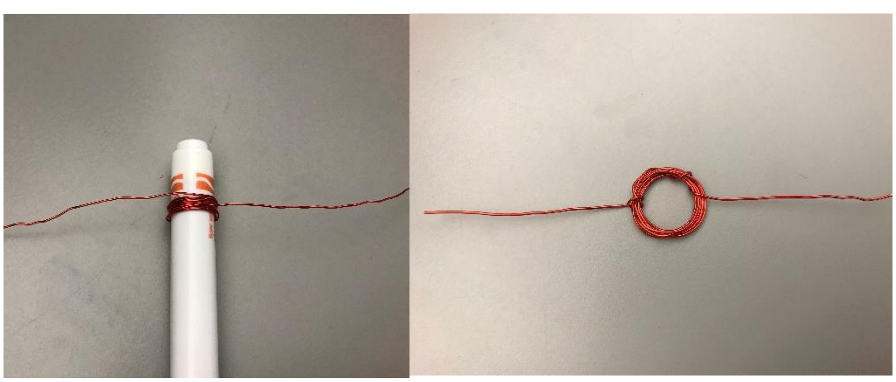


Figure 1 Make the coil of 2 mm with a dry erase marker, and wrap it symmetrically.

2. Distribute materials to each participant.

Figure 2 Materials needed for the simple motor.

3. Have each participant sand the end of the coil in the following way: one end gets sanded down all the way around, exposing the copper wire. **On the other end, sand the bottom side *only*.**

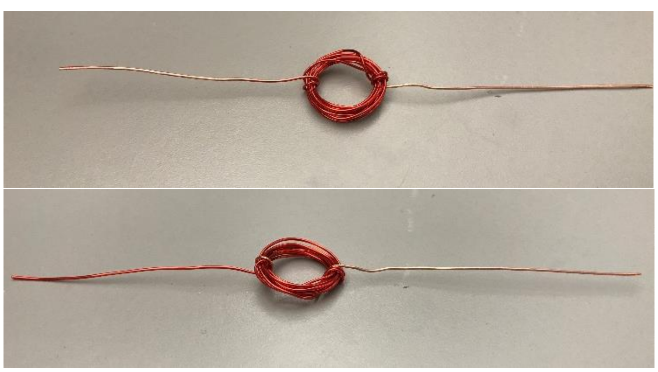


Figure 3 The copper is exposed on 3 out of 4 sides of the coil ends.

Presenter Brief:

Introductory electricity and magnetism topics are key to this workshop. Be familiar with how current flows, electromagnetic induction, circuits, and forces.

Vocabulary:

- Current – flow of electrons
- EMF or Voltage – an electrical potential difference which allows for charge to migrate from one body to another
- Conductor – a material that electrons will freely flow through
- Insulator – a material that electrons do not freely flow through, e.g. no current will flow through an insulator.

Physics & Explanation:

Middle (ages 11 - 13):

Motors convert one form of energy into another one. The simple motor presented here converts electromagnetic energy into kinetic energy. Generators are just motors in reverse; they take mechanical energy and convert it into electrical energy, generating electricity.

🔑 Motors transfer electrical energy into kinetic energy. Generators are the opposite: they convert mechanical energy into electrical energy.

A battery stores electrical energy. You can use the battery to draw current through a good conducting material, like steel or copper metal. The coil of wire in this demo is a metal wire that is coated with plastic, which is a good insulator. The plastic coating will stop the flow of current. The idea is to take off some insulation from the coil of wire in just the right way to create a motor that can keep the coil spinning until the battery dies.

🔑 Electrons move (current flows) through conducting material, and current does not flow through insulating material.

The safety pins are attached to the battery with the rubber band, and the wire coil ends go through the holes in the ends of the safety pins. The sticky putty is used to hold the battery still on the table. The magnet is placed on top of the battery, underneath the coil of wire. From here you should be able to give it an initial spin and it will continue to spin on its own. You've made a motor!

Walk around and help participants assemble the motor as in Figure 4.

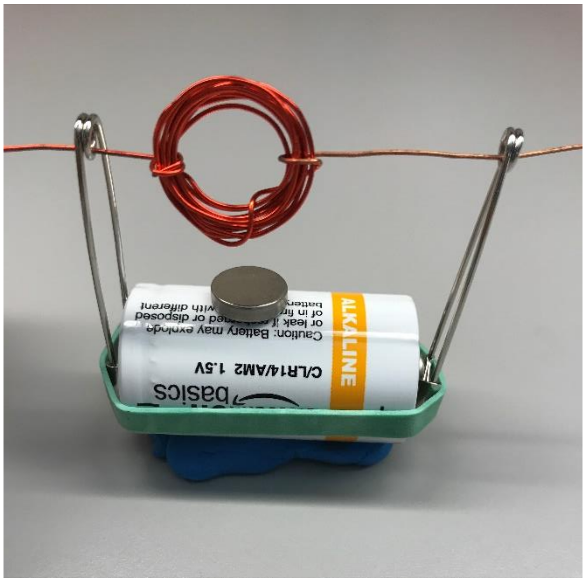


Figure 4 Assembled simple motor. Give it a spin.

This demo may take patience to get working. Some troubleshooting tips:

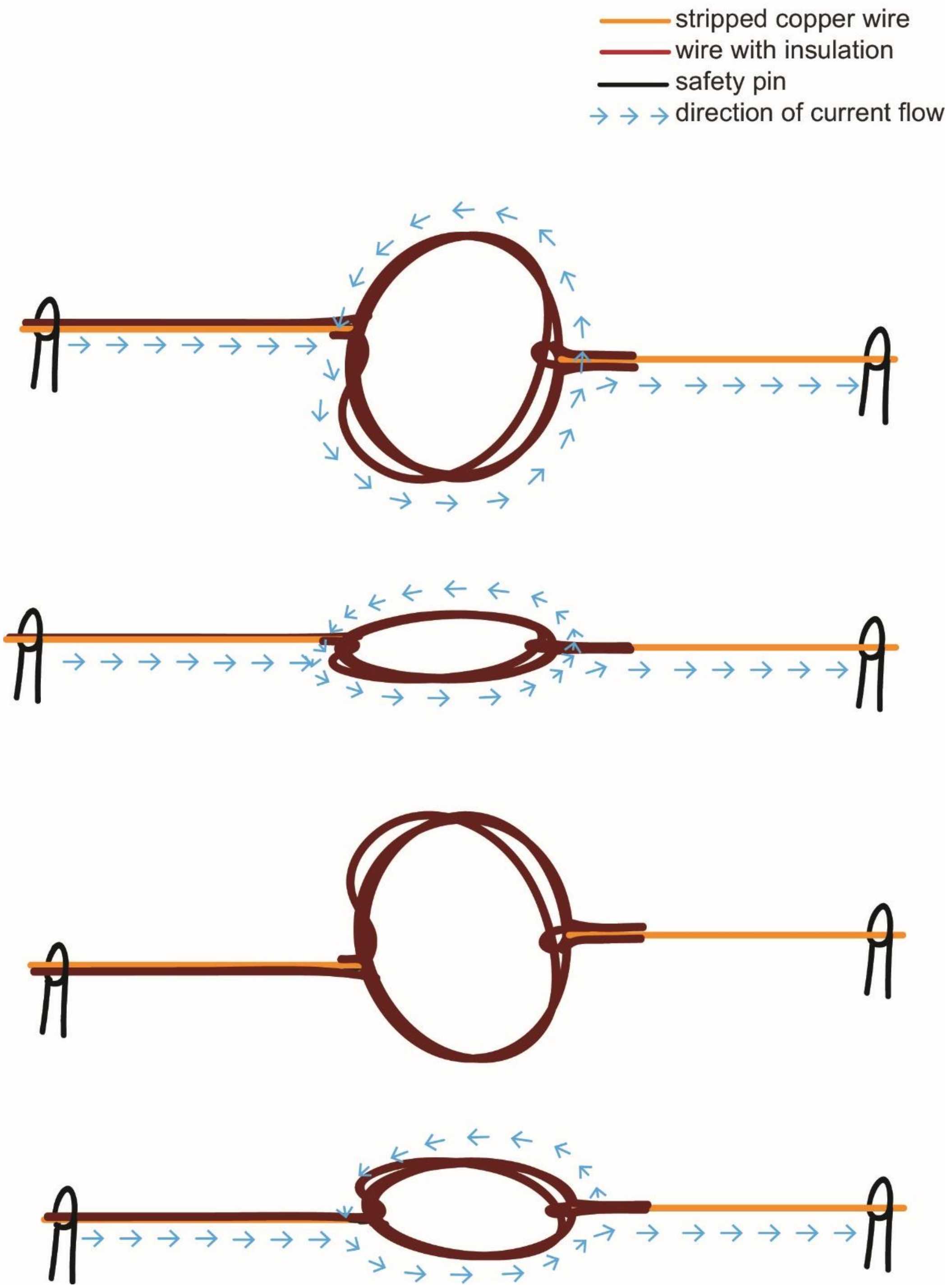
- Make sure the safety pins have good contact with the battery terminals.
- If the coil is leaning too far to one side, you may need to rewrap it so it's more symmetrical.
- Make sure you didn't sand off too much of the wire insulation—one end needs to have enough insulation on one side that the circuit is broken for a moment and keeps the magnetic field changing.
- If using a different gauge wire, adjust the number of turns for the coil; remember in general the induced magnetic field is linearly proportional to the number of coils.

Highschool and up (14+):

An initial current is pushed through the coil from the battery. When you get electric current flowing through a wire, the wire will create a magnetic field. And once you put this coil in an external magnetic field (created by the magnet), the two magnetic fields interact and the coil will spin. These concepts were realized in the 1800's by scientists like Amperé and Faraday and are the basis of many modern-day motors and generators.

When electric current flows through a wire, it produces a magnetic field. A changing magnetic flux will induce an EMF in the coil, causing current to flow through the coil.

If current was constantly flowing through the coil, then there would be a permanent magnetic field between the coil and the magnet. (If you put a compass close by the wire, you can detect the magnetic field). This permanent magnetic field would cause the coil to stay still, suspended in the magnetic field; it is only a *changing* magnetic field that will induce a force on the coil. The insulation on the coil is what breaks the circuit and keeps the magnetic field of the coil changing, and thus moving. The angular momentum the coil has gained while trying to align itself is what continues to rotate the coil at the moment the circuit is broken by the insulation.



Circuit is closed, current is flowing; the coil creates a magnetic field.

The magnetic field created by the coil repels the magnetic field of the magnet, so the coil turns to align itself to a position where the magnetic fields attract.

The insulated side of the wire breaks the circuit so no current flows, and the coil no longer has its own magnetic field. The coil's angular momentum is what keeps the coil moving.

The coil turns enough to return to all metal contact and the process starts all over again.

Additional experimenting:

- What happens if you put more magnets?
- What happens with stronger or weaker magnets?
- What about different sizes of wire?

Additional Resources:

- Resnick, Halliday, Walker *Fundamentals of Physics,* 2001. (p 701-720)