Homopolar Motor

As Presented by LIGO Science Education Center

Synopsis

Motors rely on moving electrical charges interacting with a magnetic field. This simple concept can be used to create very simple motors using just a battery, a rare earth magnet or two and a wire.

In this exercise we can make a screw spin, a piece of copper wire spin, and we can even make a battery spin.

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Necessary Materials: Battery, rare earth magnets (can be done with regular magnets, but very difficult), Wire with stripped ends (or bare wire)
Additional Materials: Extra Variety of batteries, magnets, wires, wire stripper, needle nose pliers, other conducting materials such as screws

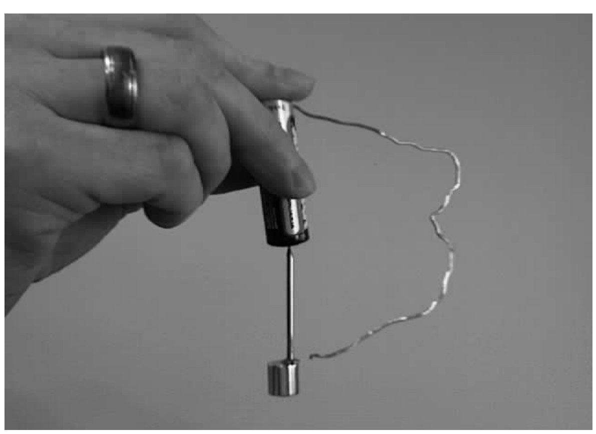
Engage:

Have students touch a conductive stripped ends of wire to a battery – what happens to the wire? **WARNING: We are essentially short-circuiting the battery – this can result in the battery and the wire becoming extremely hot. There is even the slim possibility of the battery "exploding" (not in a very dangerous way – just messy) due to the heat. Do NOT pin the wires to the battery with your bare fingers, or they may get burned.**

Explain:

You just let the chemical potential energy become heat energy.
We can also convert this energy into Kinetic energy via a motor. (Show an example of a motor.) You can create a motor as well. All moving charges are pushed on by magnetic fields (unless they move parallel to the magnetic field): Force = Charge x Velocity X Magnetic Field strength (F = q V X B). What is an electric current? It's moving electric charges, so by moving electric charges through a magnetic field (but not in line with the field), the charges are pushed by the magnetic field. Motors use this principle. We are going to create a simple motor called a Homopolar motor.

Have the students grab a nail or screw, a rare-earth magnet and a piece of wire with at least the ends exposed.
Arrange the magnet on the bottom stuck to the small nail/screw, which is then stuck to the bottom of the battery – all held in place by the magnetic force.
Next, attach a piece of wire to the top of the battery (use electrical tape).
Finally touch this wire to either the nail/screw or the magnet (if it's conductive).
The magnet and nail/screw should start spinning!

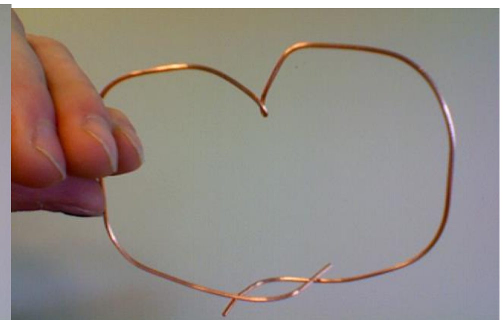


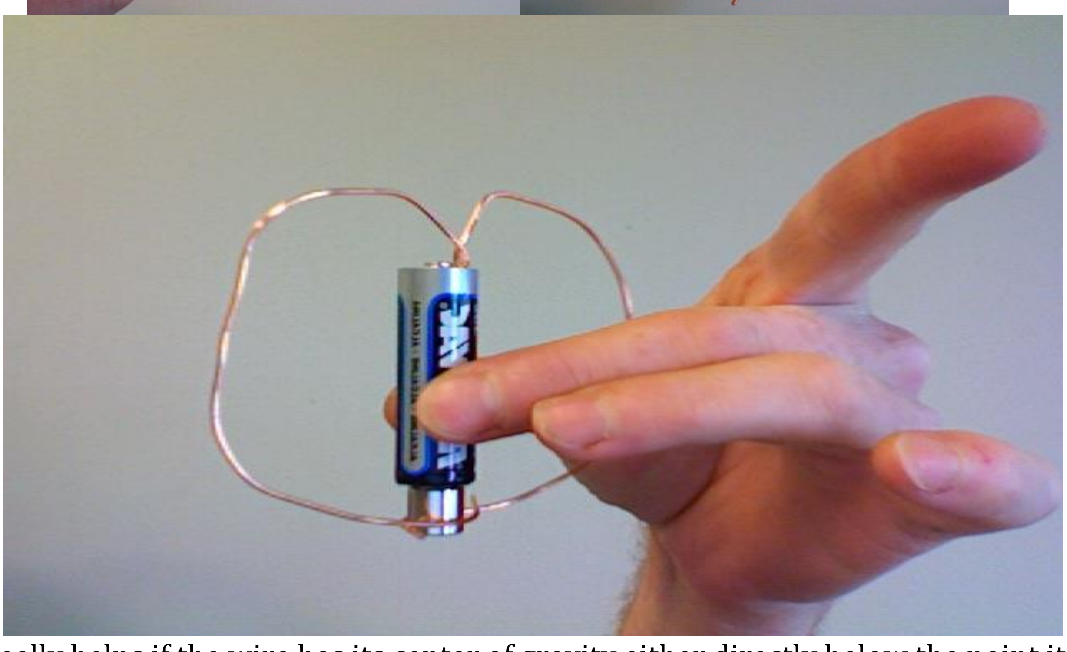
As the charges flow through the wire, the magnet pushes on them when they cross the magnetic field. According to Newton's 3rd law (For every action there is an equal and opposite reaction), the charges also push on the magnet. Since the magnet and nail/screw are the only things that can move, they start moving!

Now let's try to build a homopolar motor that has the wire moving.
There are many ways to do this – the key parts are:

1) To make sure the wire touches the top of the battery at all times.
2) To make sure the wire touches the bottom of the battery (even indirectly) at all times – this completes the circuit.
3) To make sure the wire crosses the magnetic field.
4) To make sure that there isn't much friction!

The easiest way to do this is probably to stick the magnet (if it is conductive) on the bottom of the battery, and form a balanced piece of wire that lightly sits on the battery and lightly touches the sides of the magnet.





It really helps if the wire has its center of gravity either directly below the point it balances or close to underneath the point it balances on. If the center of gravity is too far off, then the center of gravity will try to shift to directly under the point the wire hangs from, often either introducing too much friction, or more likely pulling the top off of the battery.

Extend:

Challenge students to create a homopolar motor that

1) Stays spinning for the longest time
2) Spins the fastest
3) Gets the most number of spins out of a battery.
4) Has the least amount of copper revealed (some copper is necessary to reveal to complete the circuit – but does the whole piece of copper need to be revealed)?

OR Challenge the students to create a homopolar motor that drives a "vehicle." This can be done by using a second rare-earth magnet, and making sure the batteries are smaller diameter than the magnet (or using washers as wheels).

Evaluate:

Left up to the teacher

A bit more background…

A physicist might say: $F = q V \times B$ where F is the force on the charge, q is the charge, V is the velocity of that charge X means you take a cross product and B is the magnetic field. The cross product means that only when charges cross the magnetic field (not when they go in the same direction of it) do they experience a force and the force is perpendicular to both the velocity and the magnetic field. Another way to say it is: $F = qVB\sin\Theta$ Where F is the Force, q is the charge, V is the velocity, B is the magnetic field strength and Θ is the angle between the velocity and the magnetic field.

Internet resources

http://dangerouslyfun.com/homopolar-motor
http://www.break.com/usercontent/2008/1/HOW-TO-build-a-Homopolar-Motor-434687.html
http://en.wikipedia.org/wiki/Homopolar_motor
http://blog.makezine.com/archive/2009/07/homopolar_motor_from_make_volume_01.html
http://www.evilmadscientist.com/article.php/HomopolarMotor
http://www.absoluteastronomy.com/topics/Homopolar_motor
http://www.instructables.com/id/Homopolar-Motor-With-Five-Speed-Manual-Stick-Shift/
http://atg.ga.com/EMS/defense/dc-motor/index.php
http://www.arborsci.com/detail.aspx?ID=1283
http://www.wondermagnet.com/ a source of rare-earth (particularly neodymium) magnets
http://www.youtube.com/watch?v=SWOvtGcP9J4