THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Technical Workshop: Electrical

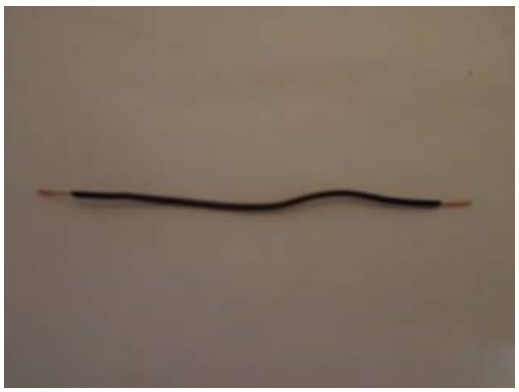
December 3, 2016

ELECTRICAL: MOTORS

I. A Simple Direct Current Motor I

1. Start with 1 piece of insulated wire, 1 “C” size battery, 1 magnet, 1 piece of electrical tape, and 1 screw.

2. Cut a piece of wire about 6” long. Use the wire strippers to strip away the ends of the wire as shown in the picture below.



3. Tape one end of the insulated wire to the positive (dimpled) terminal of the battery.

4. Attach the magnet to the screw head. Be careful you don't pinch your finger!

5. Hold the battery vertically so the negative (flat) terminal is facing down. Attach the tip of the screw to the negative terminal of the battery so the screw hangs straight down.

6. Touch the wire as close as you can to the center of the bottom side of the magnet.
    a. Does the battery spin?
    b. Try touching the wire a bit off center. Does it spin now?
    c. Try touching the wire to the edge of the magnet. Does it spin?
    d. What happens if you flip the battery over? Why? Do it!
    e. What happens if you attach the wire to the negative side of the battery? Why? Do it!

Questions:

1. What happens electrically when you touch the wire to the battery?

2. Draw a 2 dimensional picture of the direction of the magnetic field in your battery.

3. Also show in your picture above how the electricity flows through the motor.

4. Explain to the instructor why the screw spins. Hint use cross product or right hand rule as shown in the formula above. Ask the instructor if you don't get this part. Don't worry this is a hard one!

5) Why doesn’t the motor spin if the wire contacts the magnet exactly in the center?

How Does a Motor Work?

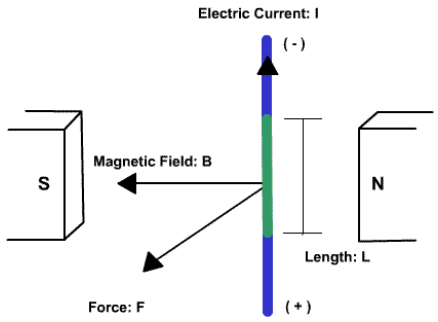
A motor converts electrical energy (from a battery or voltage source) into mechanical energy (used to cause rotation).

When a wire that carries current is placed in a region of space that has a magnetic field, the wire experiences a force.

• The size of the force, which determines how fast the motor spins, depends on:

- the amount of current in the wire
- the length of the wire
- the strength of the magnetic field

$$F = I(l \times B)$$

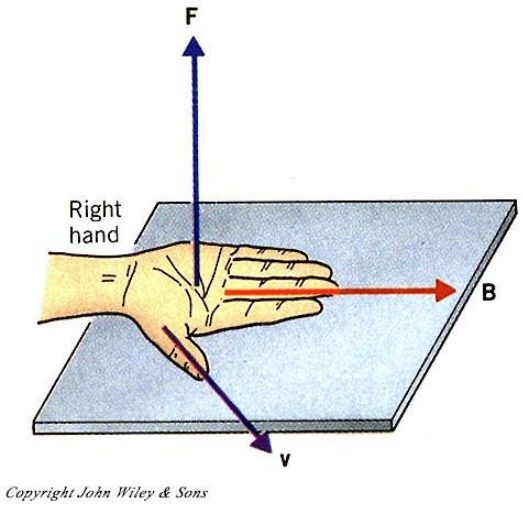


Force = (current) x (wire length) x (magnetic field)

The direction of the force, which determines which direction the motor spins, depends on:

- the direction of the current in the wire
- the direction of the magnetic field

The Right Hand Rule is used to determine the direction of the force when the direction of the current and the direction of the magnetic field are known.



Thumb = direction of current
Fingers = direction of magnetic field
Palm = direction of force

II. A simple Direct Current Motor II

1. Start with one 1 “AA” battery, one “C” battery, 2 feet of thin copper wire, wire cutters, tape, 2 paper clips, and a magnet.

2. Wrap the wire tightly around middle section of the smaller (“AA”) battery 7-10 times so that it forms a circle.

3. Wrap both loose ends of the wire 2-3 times around the circle so that it looks like the picture below. Be sure to make the ends strait and even so that it will be balanced and spin smoothly. This loop of wire will be the armature of your motor. (The part that spins)

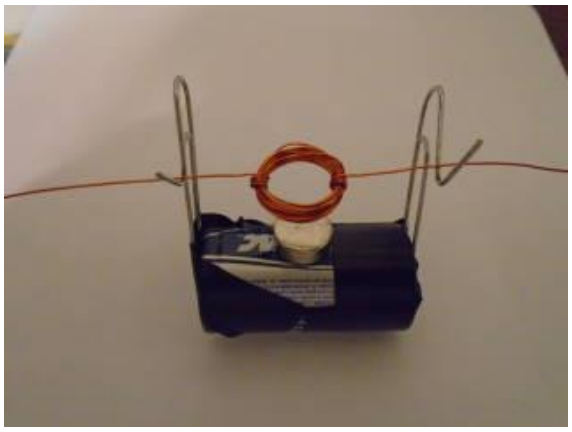
4. Hold the coil vertically, don’t lay it down flat, see the picture below. Put a piece of paper, wood or the ruler between the wire and the tabletop. **DO NOT SAND DIRECTLY ON THE TABLETOP, YOU WILL RUIN THE TABLETOP!!** Use a piece of sandpaper to remove the insulation on **only the top side** of the ends of the two wires sticking out the sides of the armature. Your instructor will demonstrate how this is done. This is important, as your motor will not spin if you sand the insulation from the top AND bottom of the wire.

5. Place the magnet on the center of the larger “C” battery.

6. Bend 2 paperclips to create a holder for your armature.

7. Tape 1 paperclip to each end of the battery. Be sure the metal of the pin touches the metal of the battery. This will be the cradle of the motor, it will hold up the armature.

8. Place the ends of the armature onto the paperclips so that the loop hangs directly above the magnet.



9. Lightly spin the armature and watch what happens. The wire must be well balanced for the motor to work.

    a. Make sure the ends of the wire come straight out the sides of the armature.
    b. Move the coil directly over the top of the magnet.
    c. Make sure the bare ends of wire (where you sanded away the insulation) touch the paper clips. You may have to re-sand the wire further in toward the coil.
    d. If the armature jumps out of the cradle, it is probably too close to the magnet.
    e. It might help to rotate the battery slightly around it center. Why?

The direction that the motor spins can be controlled by changing the direction that the current runs through the rotor, try witching the battery polarity. It can also be changed by changing the direction of the magnetic field, try flipping the magnet over.

The speed at which the motor spins depends on the force experienced by the wires which make up the rotor. It is possible to increase the force, and therefore the motor speed by:

- Increasing the number of loops in the coil which makes up the rotor.
- Increasing the current, try a bigger or smaller battery.
- Increasing the magnetic field, try using two magnets.

Question:

1. Draw a picture of how the electricity flows through the motor as well as the direction of the electric field. Use the cross product to explain to the instructor why the armature spins.

2. If you have time, use the smaller “AA” battery instead of the “C” battery for your motor base. Does in work better or worse? Why?

Troubleshooting

Things to consider if the motor doesn't spin

- Has the rotor been stripped correctly? Hold the plane of the loop so that it is oriented vertically. One of the straight sections of the rotor should be stripped completely (from rotor to end); the other straight section should be stripped on the *top* only.

- Is the circuit complete? Check every connection.

- Is the rotor level and directly above the magnet? Adjust the rotor, paperclip supports and magnet until both straight sections of the rotor are perfectly horizontal, both paperclip supports are at the same height, and the magnet is directly underneath the rotor when the rotor is oriented so that the plane of the loop is vertical.

- Is the rotor close to the magnet? The magnetic field is strongest nearest to the magnet. When the plane of the rotor is oriented vertically, the bottom of the rotor should be as close to the magnet without touching.

A short quiz to see what you've learned.

Fill in the blanks.

1. Motors are devices that convert _____ energy into _____ energy.
2. The basic principle behind the simple DC motor is that wires that carry _____ experience _____ when placed in regions of space that have _____.
3. Only sections of wire that carry current in a direction _____ to a magnetic field experience forces.
4. The speed at which the rotor of a motor spins depends on three important factors: _____, _____, and _____.
5. The direction that the rotor of a motor spins depends on the _____ rule.