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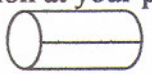
Spring 04

PH 4B
Direct Current (D.C.) Electric Motor Project

- See the *Labs* portion of the course website for *D.C. Electric Motor* handouts that provide assembly ideas & instructions for several styles of motors.
- See course laboratory outline for scheduled workdays in lab and final project due date. You will most likely spend time outside of class, working on your motor.
- Work in groups of two students. You MUST do all of the mechanical work on your motor yourselves, no outside help is allowed unless it is from your instructor. NOTICE: You may, however, discuss design ideas of your electric motor with other individuals.

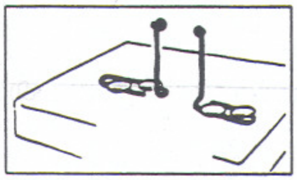
- You must make use of electromagnets that are made by you and your partner. NO PERMANENT MAGNETS ARE PERMITTED!
- You may NOT use any components or parts from an electric motor kit or a previously existing electric motor.
- You must use some sort of a brush configuration at your points of contact, simply stripping a part of the wire is not allowed e.g. 

- Recycled materials are available upon request (ask Matt or Katherine).
- You will be supplied with a power supply when you turn/test your electric motor.
- Write you name and partner's name on the motor before turning it in. You will get your motors back, however Katherine may ask if you want to donate your motor☺).

PROJECT: A Do-It-Yourself Recipe for a Simple Homemade Motor*

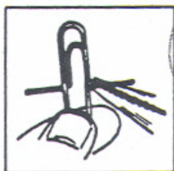
The finished motor shown to the left can be built with the following commonplace tools and materials: eight thumbtacks, three 2-inch paperclips, two 3 1/2 inch nails, needle-nosed pliers, electrical or adhesive tape, a wooden board about five inches square, about 20 feet of No. 20 insulated copper wire and a knife or sandpaper to scrape the ends with. Two 1 1/2 volt dry cells provide an adequate power supply.

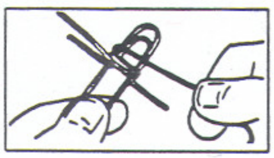
Step 1. The first step in making the motor is straightening the smaller loop of one of the paper clips, and then twisting it so that it stands upright at right angles to the larger loop. Then use the pliers to bend a tiny loop in the upright end. Do the same with a second paper clip.



Step 2. Next, attach the paper clips to the board with tacks as shown. The upright ends of the clips should be about an inch apart. The tacks should be loose enough for final adjustment later. These clips are the supports for the axle of the motor's rotor.

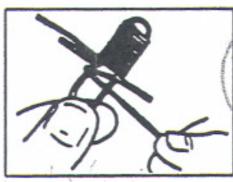
Step 3. Next make the rotor. With pliers, bend the ends of the third paper clip perpendicular to the clip's midpoint as shown. The ends, which will serve as the rotor's axle, should each be about a half-inch long.





Step 4. Leaving one inch free, wrap the copper wire tightly around the rotor clip, working out from the middle. Wind the turns of wire closely together, but not so tightly that the clip is bent out of shape.

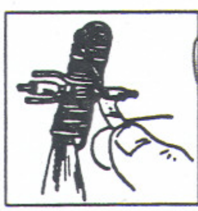
Step 5. Wrap about 20 coils out toward the end of the rotor clip. Then take the wire back to the center and wrap—in the same direction—an equal number of turns around the other half. These coils will make the clip an electromagnet.

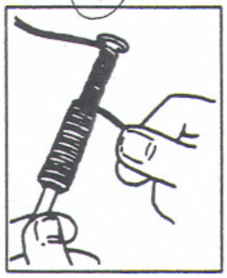


Step 6. When the copper wire has been wound around the second half of the rotor clip as shown, it is brought back to the center of the clip. The ends of the wire will serve as the rotor's *commutator*, which reverses its current with each rotation.

Step 7. The next step is to cut the ends of the wire so that they are slightly shorter than the projecting end of the clip. Then scrape the coating off the ends of the wires making sure to expose the bare copper.

Then take two strips of electrical or adhesive tape—each about 1/4 inch wide and 2 inches long—and wrap them around the axle next to the clip as shown. This tape keeps the rotor-clip axle in the paper clip supports. The center of gravity of the finished rotor should be along the axle so that it will twirl without wobbling.

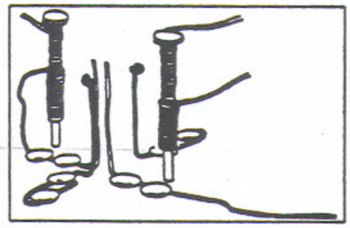




Step 8. Make two stationary electromagnets by wrapping each nail with wire, leaving about 9 inches of wire free close to the head. Wind the wire evenly for about 2 1/2 inches down from the top, then about halfway back up again. Both nails should be wound in the same direction.

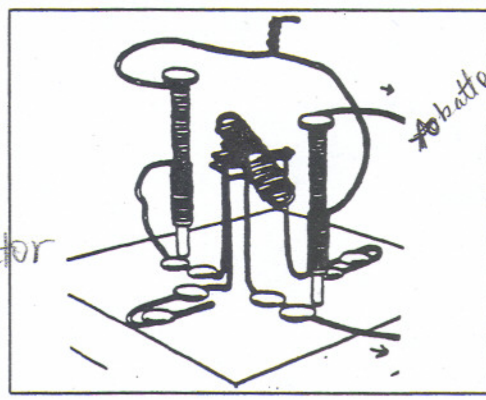
Leave about 6 inches of wire sticking out from the middle of each nail and cut it. Each nail should now have a 9-inch and a 6-inch tail. Scrape about 3/4 inch of insulation from the end of each tail, exposing the bare copper.

Step 9. Hammer the nails into the board just far enough apart to make room for the rotor. Tack the 6-inch tail from one nail to the board. Lead it to within 1/4 inch of either support and bend it up so its tip is slightly higher than the support. Do the same with an unattached 12-inch length of wire. These form the *brushes*. About 3/4 inch of insulation should be thoroughly scraped from each end of the 12-inch length of wire. Now all loose ends of wire are scraped free of insulation.



Step 10. Fit the axle of the rotor into the loops of each support so that the rotor's commutators, when twirling, will make contact with the brushes. Twist the end of the 6-inch tail from the second nail around the 9-inch wire from the first nail. The 9-inch wire from the second nail will connect with the dry-cell terminal. Link the free end of the 12-inch wire to the opposite dry-cell terminal and the circuit is complete.

It is important to make final adjustments so that the rotor will spin freely. As the rotor spins, both commutators should touch the brushes simultaneously. Only then will current be established in the entire circuit, making the rotor and nails electromagnets. Each time the rotor makes a half-turn, the direction of current in the rotor alternates, changing its magnetic field polarity. It may be necessary to give the rotor a gentle nudge for the motor to operate, just as you sometimes have to do with some types of electric shavers.



Utilizing the fact that like magnetic poles repel each other and unlike poles attract, can you explain the operation of this motor?

"Your motor must run for 20 seconds. You must use insulated wire. You may use more than 3 volts."

*Courtesy of Time-Life, Inc.

The Johnson D.C. Electric Motor Recipe

Ingredients:

two 2 5/8" pieces of 12 ga. copper house wire
two 8 inch pieces of 12 ga. copper house wire
one strong ceramic (1 13/16" x 13/16" x 3/8") magnet
(or) two ceramic (3/4" dia. x 3/16") magnets
3' of 22 ga. copper magnet wire
one "D" size alkaline battery, 1.5 volts
foam block 3" x 5" x 2" (L x W x H)
razor blade
wire cutters

Strip the insulation from the two 2 5/8" pieces of 12 gauge. Copper wire and form them as shown in figure 1 (ref. A1). The two pieces of wire just formed will become the holding rails for the battery. Place them into the styrofoam block as shown in figure 1 (ref. A2). Next, take the two 8" 12 gauge. Copper wires and strip them as shown in figure 1 (ref. B1). Form them as shown in figure 1 (ref. B2). Place them in the styrofoam block so the wire touches the battery as shown in figure 1 (ref. B3).

Wrap six turns of 22 gauge copper transformer wire around two of your fingers. Try to keep the turns as even and the center of the coil as symmetric as possible. Also wrap the loose ends of the coil wire to hold the coil together as shown in figure 1 (ref. C). The ends of the coil wire will serve as the axle for rotation.

The most important part of this motor is the commutator. The commutator is formed by taking the coil and holding it at 90 degrees to a flat surface and removing 1/2 or 180 degrees of the insulation on both axles. Be sure that the insulation is removed on the same side of both axles and not to flatten them with the razor blade. Cut the length of each axle to about two inches long.

Install the coil assembly into the indented area as shown in figure 1 (ref. D). The coil assembly must be balanced. Balancing the coil is necessary since there is an extra stand of wire on one side of the coil. Wrap a small piece of wire on the lightest side of the coil to balance it. This will have to be done by trial and error.

Install the magnet as shown in figure 1. Check to see that the coil assembly rotates freely. Install the battery into its holder. The motor should begin to run. You may at this point need to give it a small push start. Adjust the position of the magnet for optimum operation by sliding the magnet back and forth under the coil. The rotation may be reversed by flipping over the magnet or by reversing the battery.

The successful operation of this motor lies with the precision of the insulation removal, and the symmetry and balance of the coil assembly. When the coil assembly is in contact with the battery, the coil will repel against magnetic fields of the permanent magnet. As it rotates, the insulation on the axle interrupts the current flow to the coil assembly allowing it to continue to rotate. The process repeats with each turn.

Many variations are possible with this motor. You can build different size coils, change the number or turns, and use thinner or thicker wire. I have made one with a very fine wire hot glued on a thicker axle, which has run continuously for nine months on one alkaline battery. I have also designed a half loop motor (unheard of) that spins quite well. With a strong neodymium magnet and a coil made of several turns finer wire, I have been successful in using a solar cell and a potato battery to run it.

References

1. Harris Benson, University Physics, (John Wiley & Sons, Inc., New York, 1991), p. 577.
2. D. Rae Carpenter, Jr. and Richard B. Minnix, The Dick and Rae Physics Demo Notebook, (Dick and Rae, Inc., Lexington, VA, 1993), p. B-075.

The Johnson D.C. Electric Motor Plans

(Actual Size)