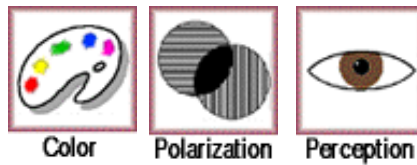
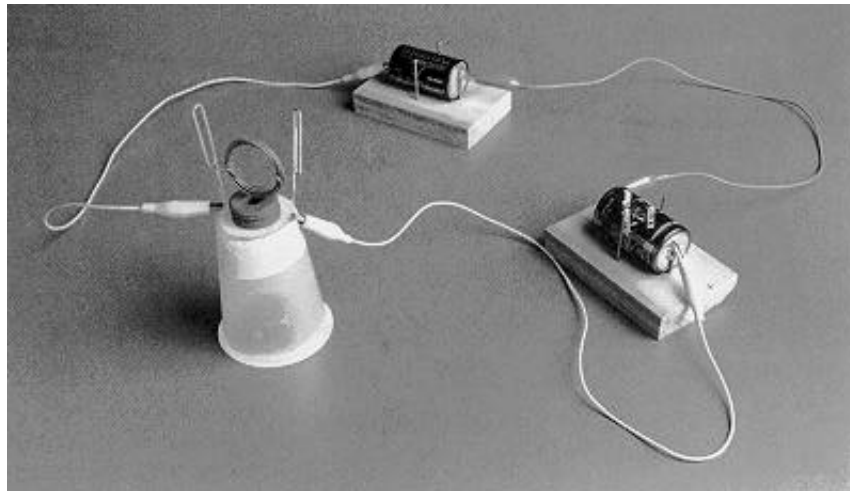




## Stripped Down Motor

As motors go, this is about as simple as it gets.



A coil of wire becomes an electromagnet when current passes through it. The electromagnet interacts with a permanent magnet, causing the coil to spin. Voila! You have created an electric motor.

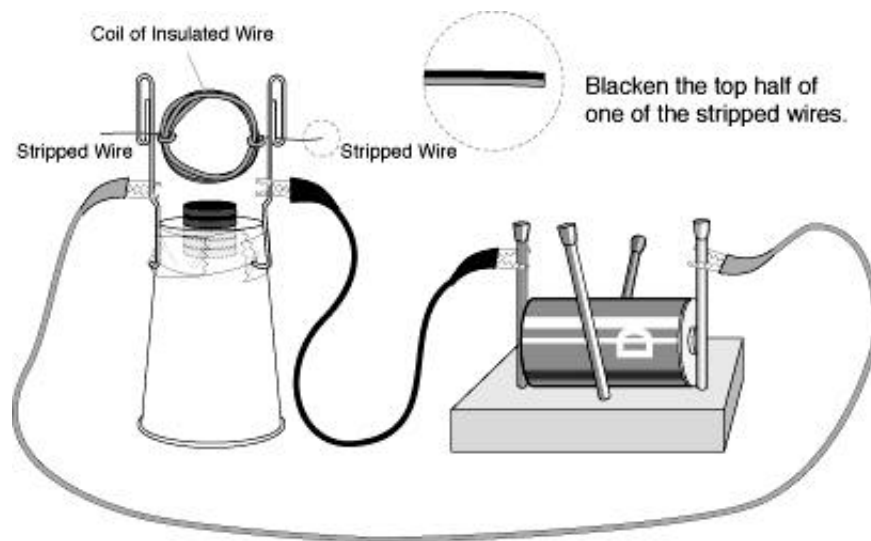
**materials** \_\_\_\_\_

- ✓ **5 small disk or rectangular ceramic magnets** (available at Radio Shack).
- ✓ **2 large paper clips.**
- ✓ **A plastic, paper, or Styrofoam cup.**
- ✓ **A solid (not stranded) enameled or insulated 20-gauge copper wire**, about 2 feet (60 cm) long.
- ✓ **Masking tape.**
- ✓ **A battery or power supply.** We have successfully run motors on one 1.5 volt D battery; additional batteries seem to make it easier to get the motor to run. You may want to try 6 volt lantern batteries. We have also had excellent results using a power supply (battery eliminator) set to about 4 volts. The advantage of the power supply is that it will supply a substantial current over a period of time. Unlike batteries, it doesn't have to be replaced. Experiment with what you have, and use whatever works!
- ✓ **2 electrical lead wires with alligator clips at both ends** (available at Radio Shack).
- ✓ **Wire strippers** (if you are using insulated wire).
- ✓ **Sandpaper** (if you are using enameled wire).
- ✓ **A black, waterproof marking pen.**
- ✓ **A battery holder.** (See "Assembly" for instructions.)
- ✓ **Adult help.**

## assembly \_\_\_\_\_

(30 minutes or less)

Wind the copper wire into a coil about 1 inch (2.5 cm) in diameter. Make four or five loops. Wrap the ends of the wire around the coil a couple of times on opposite sides to hold the coil together. Leave 2 inches (5 cm) projecting from each side of the coil, and cut off any extra. (See diagram.)



If you are using insulated wire, strip the insulation off the ends of the wire projecting from the coil. If you are using enameled wire, use the sandpaper to remove the enamel. Color one side of one of the projecting ends black with the marking pen. (Note: It is very important that the orientation of the painted side corresponds to the orientation shown in the drawing below. If the coil is held in a vertical plane, paint the top half of one of the wires black.)

Turn the cup upside down and place two magnets on top in the center. Attach three more magnets inside the cup, directly beneath the original two magnets. This will create a stronger magnetic field as well as hold the top magnets in place.

Unfold one end of each paper clip and tape them to opposite sides of the cup, with their unfolded ends down. (See diagram.) Rest the ends of the coil in the cradles formed by the paper clips. Adjust the height of the paper clips so that when the coil spins, it clears the magnets by about 1/16 inch (1.5 mm). Adjust the coil and the clips until the coil stays balanced and centered while spinning freely on the clips. Good balance is important in getting the motor to operate well.

Once you have determined how long the projecting ends of the coil must be to rest in the paper-clip cradles, you may trim off any excess wire. (The length of the projecting ends depends on the separation of the paper-clip cradles, which in turn depends on the width of the base of the cup you are using. See diagram.)

If you are using a battery, place it in a battery holder. You can make your own from a block of wood and four nails, as shown in the diagram. Use the clip leads to connect the battery or power supply to the paper clips, connecting one terminal of the battery to one paper clip and the other terminal to the other paper clip.

Give the coil a spin to start it turning. If it doesn't keep spinning on its own, check to make sure that the coil assembly is well balanced when spinning, that the enamel has been thoroughly scraped off if enameled wire has been used, that the projecting end has been painted with black pen as noted, and that the coil and the magnet are close to each other but do not hit each other. You might also try adjusting the distance separating the cradles: This may affect the quality of the contact between the coil and the cradles.

Keep making adjustments until the motor works. Have patience! The success rate with this design has been quite good.

**what's going on?** \_\_\_\_\_

Current flows through the wire coil and creates an *electromagnet*. One face of the coil becomes a north pole, the other a south pole. The permanent magnet attracts its opposite pole on the coil and repels its like pole, causing the coil to spin.

Another way to describe the operation of the motor is to say that the permanent magnets exert forces on the electrical currents flowing through the loop of wire. When the loop of wire is in a vertical plane, the forces on the top and bottom wires of the loop will be in opposite directions. These oppositely directed forces produce a twisting force, or *torque*, on the loop of wire that will make it turn. (See [Motor Effect Snack](#).)

Why is it so important to paint half of one projecting wire black? Suppose that the permanent magnets are mounted with their north poles facing upward. The north pole of the permanent magnet will repel the north pole of the loop electromagnet and attract the south pole. But once the south pole of the loop electromagnet was next to the north pole of the permanent magnet, it would stay there. Any push on the loop would merely set it rocking about this equilibrium position.

By painting half of one end black, you prevent current from flowing for half of each spin. The magnetic field of the loop electromagnet is turned off for that half-spin. As the south pole of the loop electromagnet comes closest to the permanent magnet, the paint turns off the electric current. The inertia of the rotating coil carries it through half of a turn, past the insulating paint. When the electric current starts to flow again, the twisting force is in the same direction as it was before. The coil continues to rotate in the same direction.

## etcetera

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In this motor, the sliding electrical contact between the ends of the coil of wire and the paper clips turns off the current for half of each cycle. Such sliding contacts are known as *commutators*. Most direct current electric motors use more complicated commutators that reverse the direction of current flow through the loop every half cycle. The more complicated motors are twice as powerful as the motor described here.

This motor can also be used to demonstrate how a generator works. Try hooking up the ends of the paper clips to a sensitive galvanometer instead of the battery. Spin the coil and see if any current registers on the meter.



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