

# **Building A Simple, Powerful Electric Motor**

Awesome Design by Doug Prime

## **Materials Needed**

- steel rod, 1/8" diameter x 7" long, **straight** (could use a coat hanger)
- (2) 8d common nails - 2 1/2" long with a flat head
- magnet wire, 20 ft., 22 gauge (Radio Shack/ electrical cat.)
- 35mm film canister, round with cover
- plywood or pine board, 6" X 6" piece
- (2) plywood or pine board, 3" x 1" x 1/2" pieces
- (2) fender washers, 1" diameter X 1/8" hole (or 2 plastic jewelry beads)
- steel pipe strap, 12 1/2" long (hardware store)
- (2) strong ceramic magnets, Radio Shack part no. 64 – 1877
- stranded hook-up wire, 16 in., 12 gauge (Radio Shack/ electrical cat.)
- (2) alligator clip test leads (Radio Shack/ electrical catalog)
- 6V lantern battery or 4 D-cell batteries – alkaline or rechargeable
- duct tape
- electrical tape
- sandpaper
- mini hot melt glue sticks

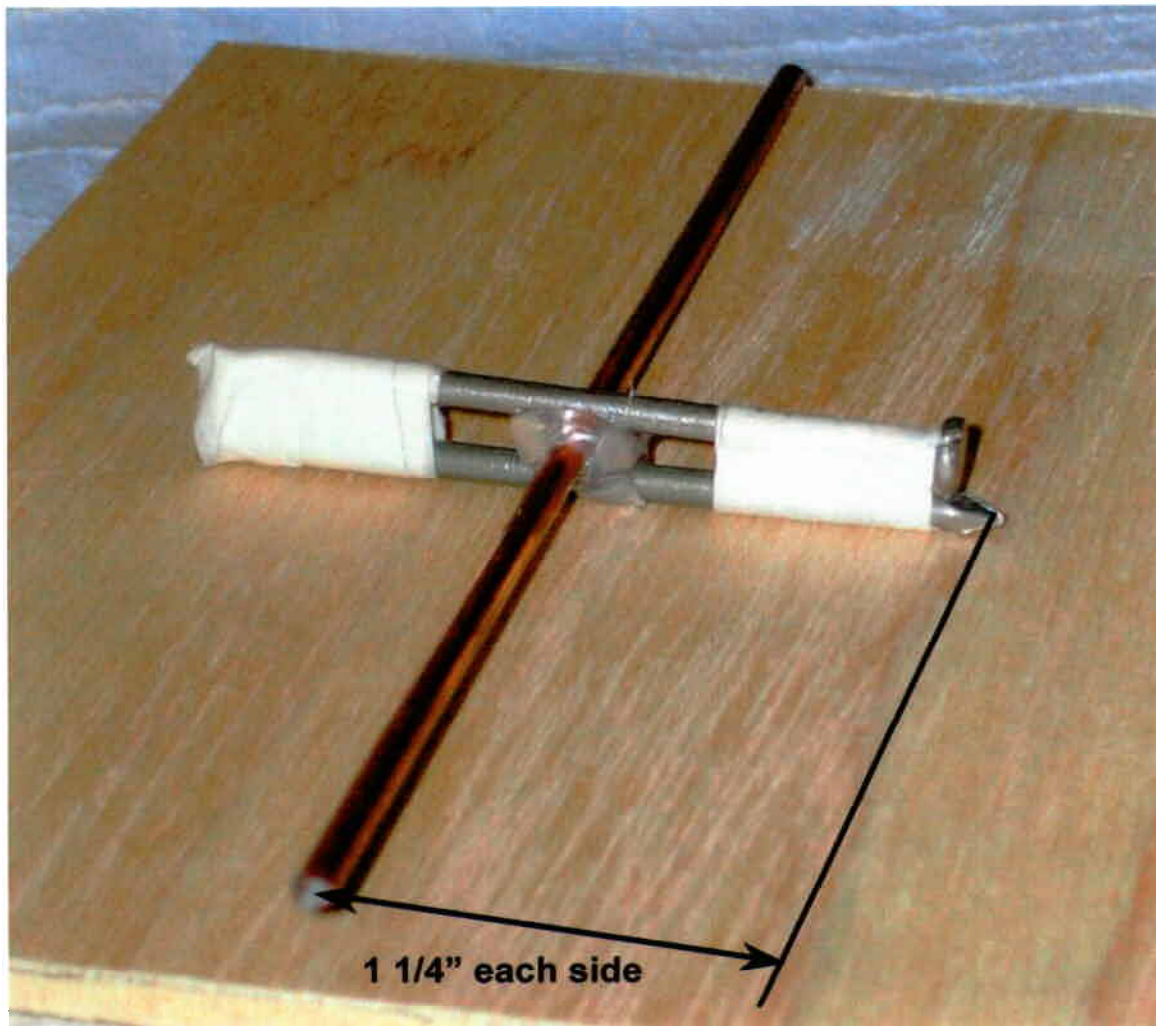
## **Tools Needed**

- hand saw (or a band saw)
- drill (or a drill press)
- wire stripper/ cutter with 12 or 14 gauge hole (to cut and strip wires)
- aviation snips (to cut pipe strap)
- bolt cutters (to cut steel rod/ coat hanger – or use aviation snips)
- pliers (to bend pipe strap)
- hammer (to flatten pipe strap)
- small flathead screwdriver
- mini hot melt glue gun
- ruler
- fine point marker

## STEP 1: Making the Armature - An Electromagnet on a Stick

- A) Tape the 2 nails together using electrical tape (or masking tape), with their opposite ends touching (head to tip).
- B) Stick the steel rod between the nails and slide the nails to the middle of the rod. If you can't get the steel rod to fit between the nails, force the screwdriver between the nails and twist it to help open the gap. **Make sure the steel rod is placed exactly at the center of the nails.** Hold the nails perpendicular to the rod and glue in place with hot glue.

### **Making the Armature**

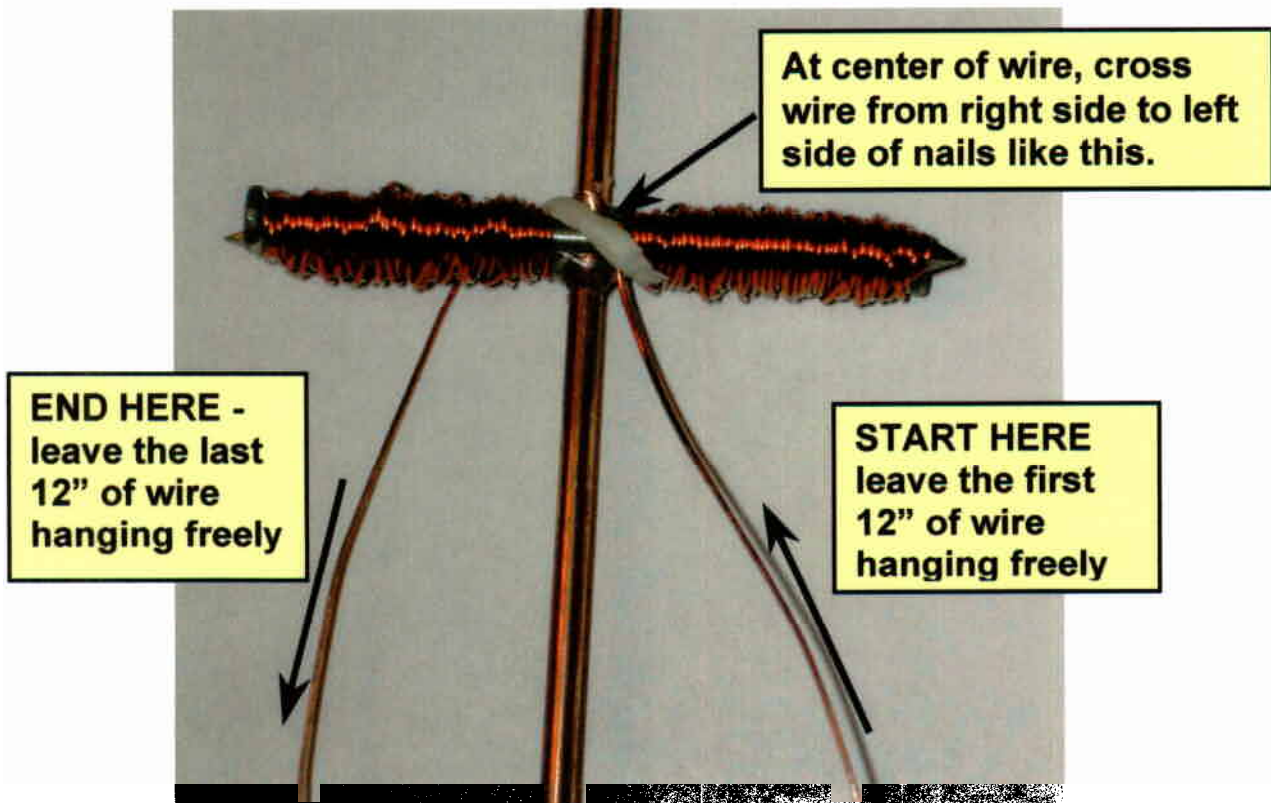


The electromagnet is made by wrapping the magnet wire onto the nails. **When you wrap your electromagnet, all the turns of wire must be going in the same direction when you look at the coil from one end, or your magnet will not work** because it will have 2 like poles (instead of a North and a South pole).

C) Fold the magnet wire in half and mark the center with a piece of tape.

D) Leave the first 12" of the wire free and unwrapped. Place the wire over the top of the nails just to the right of the steel rod, and wrap the wire away from you. **Keep wrapping the wire back and forth STAYING ON THE RIGHT SIDE OF THE NAILS until you get to the center of the wire. Then make one more turn while crossing the wire to the other side of the nails.** Now, flip the nails around and continue wrapping the wire – on this side you will be wrapping the wire toward you (although the turns are still going in the same direction when you look at the coil from the end). Be sure to leave the last 12" of wire hanging freely at the end of the coil.

### Wrapping the Electromagnet



The two ends of the wire coil that you left sticking out are called the electromagnet leads, because they lead electricity into and out of the coil. Magnet wire is painted with enamel paint to insulate the wire, so you must sand the paint off the wire in order to make an electrical connection to the bare copper.

- E) Sand both leads all the way back to the electromagnet.
- F) **Test your electromagnet:** Connect the leads to the battery and hold each end of the electromagnet up to the same pole (side) of a permanent magnet. One end of the electromagnet should attract the permanent magnet, and the other end should repel it (although the repelling force may be weak). If you feel the same force at both ends of the electromagnet, the turns of wire are not going in the same direction; if so, carefully unwrap the wire on one side of your magnet, and rewrap it with the turns going in the opposite direction.

## **STEP 2: Making the Commutator - the Motor's Switch**

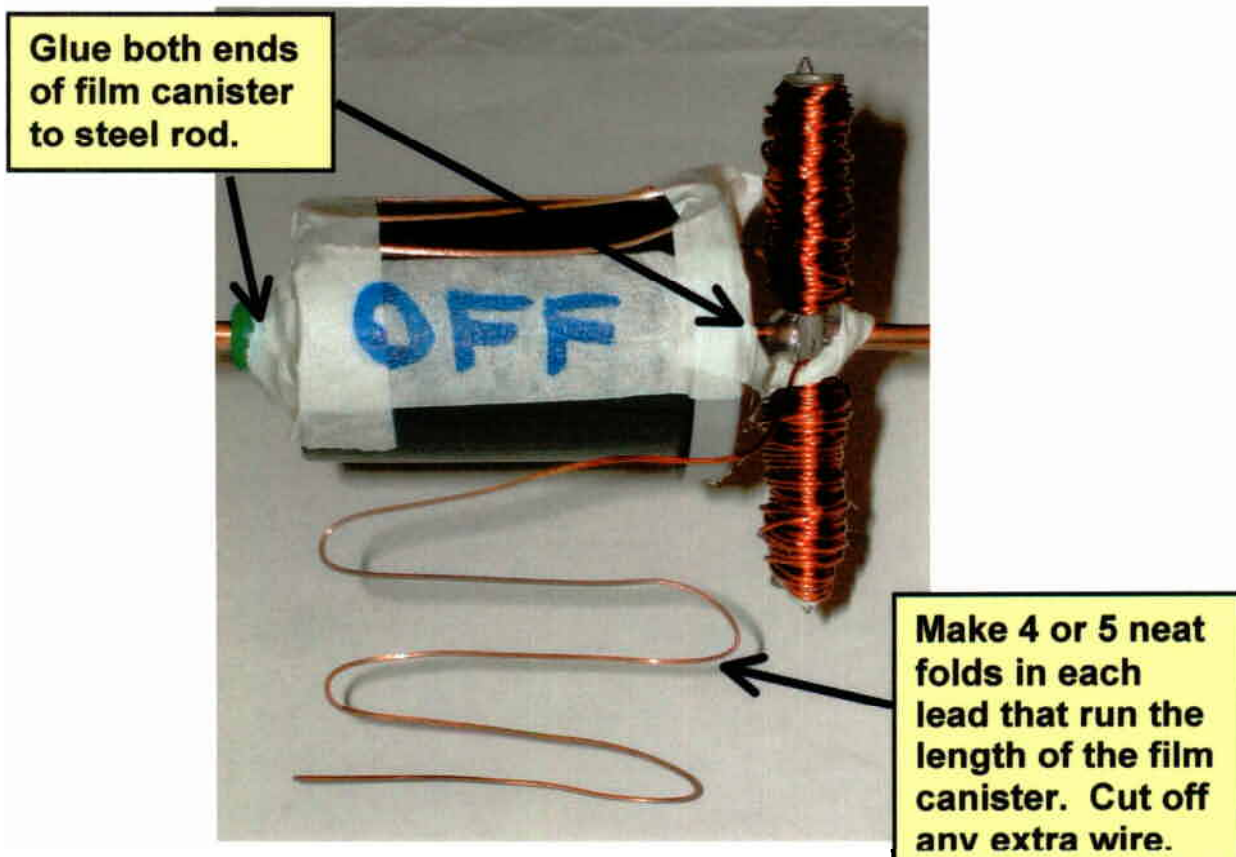
The commutator, which is the other part of the armature, is just a fancy switch for the electromagnet. It turns the electromagnet on and off, and reverses the poles of the electromagnet from north to south, and south to north, every half turn. The commutator in this motor is made by folding the leads of the electromagnet to form 2 zigzags. When the commutator spins, the two zigzags touch the brushes, which are connected to the battery, allowing the electricity to flow into the wire coil. When electricity flows into the wire coil, it becomes an electromagnet.

- A) Using a nail, punch holes in the bottom of the film canister, and in its lid, exactly at the center (look for tiny bumps in the plastic).
- B) Slide the film canister onto the steel rod until it is about 1/2 in. away from the electromagnet, and hot glue it in place (glue both ends).

C) Hold the electromagnet straight up and down and place a piece of tape along the film canister on the side facing you, and also on the opposite side (see photo below for location). These are the motors “off spots” – when the brushes rub against these tape spaces, the motor will be off.

D) Fold each lead of the electromagnet back and forth along the length of the film canister 4 or 5 times to form a zigzag.

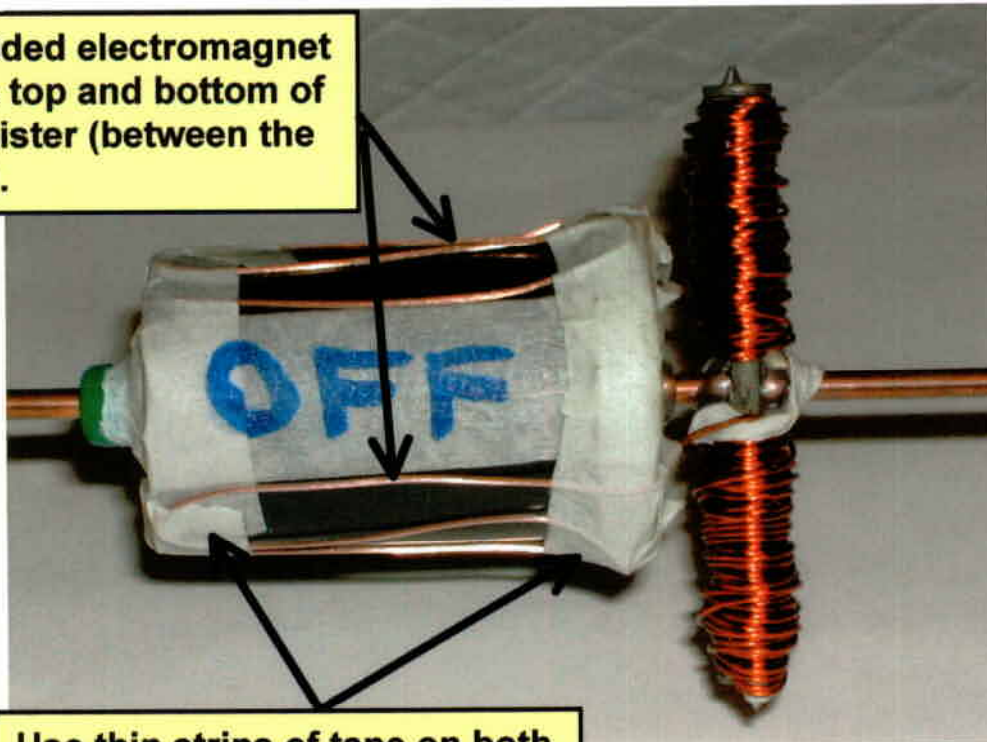
### Making the Commutator



E) Tape the folded electromagnet leads to the top and bottom of the film canister (between the 2 pieces of tape that mark the “off spots”). Each end of the electromagnet should line up with one of its folded leads. Tape the electromagnet leads to the film canister with thin strips of masking tape that just cover the ends of the folds (see photo below). The brushes rub against the leads to get electricity into the electromagnet, so be sure not to cover too much of the wire with tape.

## A Finished Commutator

Tape the folded electromagnet leads to the top and bottom of the film canister (between the "off spots").



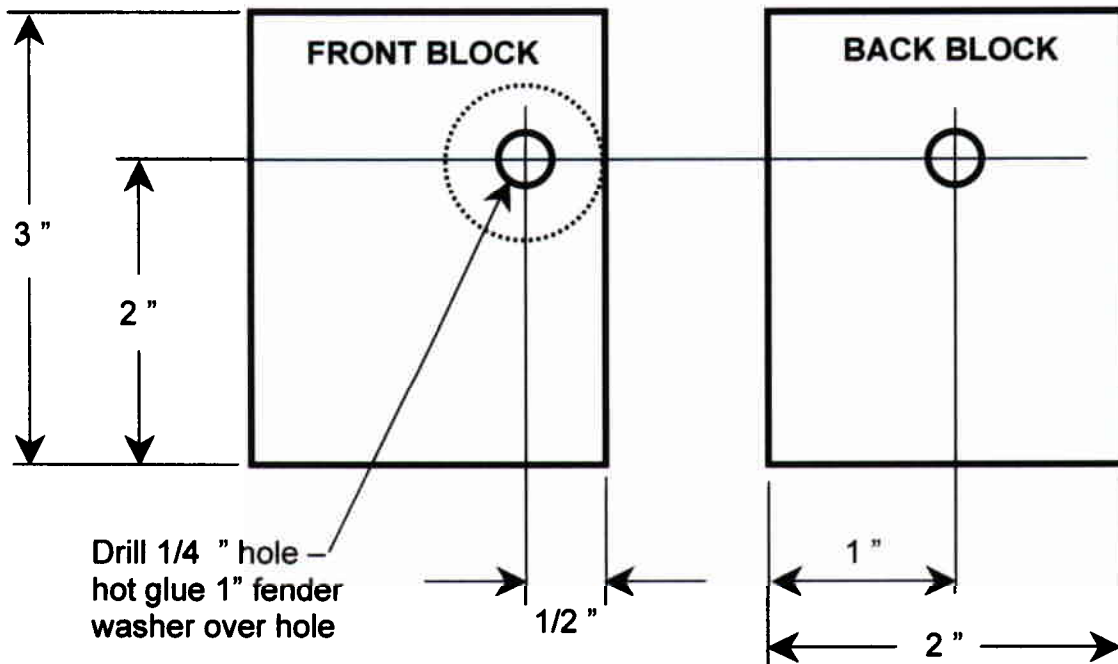
Use thin strips of tape on both ends of the folds, so you don't cover too much of the wire.

## STEP 3: Making the Bearing Blocks

A motor must have bearings on both ends to hold the shaft in place and allow it to spin easily. Usually ball bearings are used so that the motor will run smoothly and spin with very little friction. For this motor, metal fender washers are used as bearings (although plastic jewelry beads also work pretty well). You can put a little cooking oil in your "washer bearings" to reduce friction and increase the speed of your motor; or coat the holes of the washers with graphite (pencil lead), which is also a good lubricant.

- A) Cut 2 blocks of wood that are about 2" wide X 3" high X 1/2" thick.
- B) Mark lines on the blocks 2" up from the bottom to mark the height at which the holes will be drilled. On the front block, drill a 1/4" hole that is 1/2" in from the right side (see drawing below). On the back block, drill a 1/4" hole that is about in the middle of the block, at a height of 2".
- C) Now hot glue a 1" fender washer (with a 1/8" hole) over the hole you drilled in each bearing block. Be sure that the washer is centered, and make sure you don't get any glue into the washer's hole.

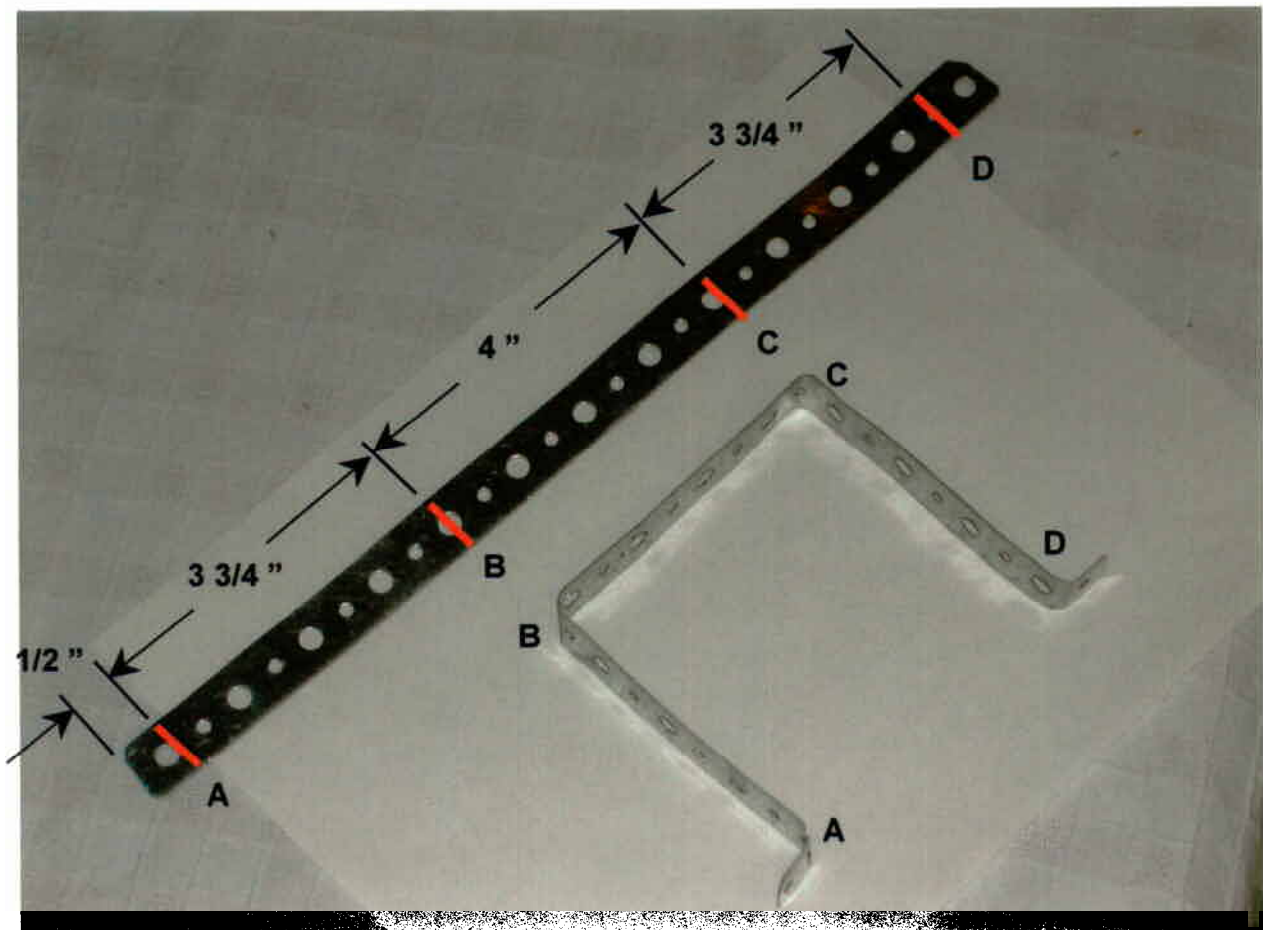
### Making the Bearing Blocks



## STEP 4: Making the Magnet Frame

- A) Cut a piece of pipe strap that is 12 1/2" long. Snip off the corners so there are no sharp edges.
- B) Make a mark "A" that is 1/2" in from the end of the pipe strap. Then make 3 more marks, B, C & D, that are spaced at the following distances: 3 3/4", 4" and 3 3/4" (see the photo below). The last mark you made should be 1/2" in from the other end of the pipe strap.
- C) Bend the pipe strap on the 4 lines you drew to make the magnet frame as shown in the photo. The frame is 3 3/4" high and 4" across the top. It has two 1/2" legs that are bent out at each end.

### **Making the Magnet Frame**





## STEP 5: Making the Brushes

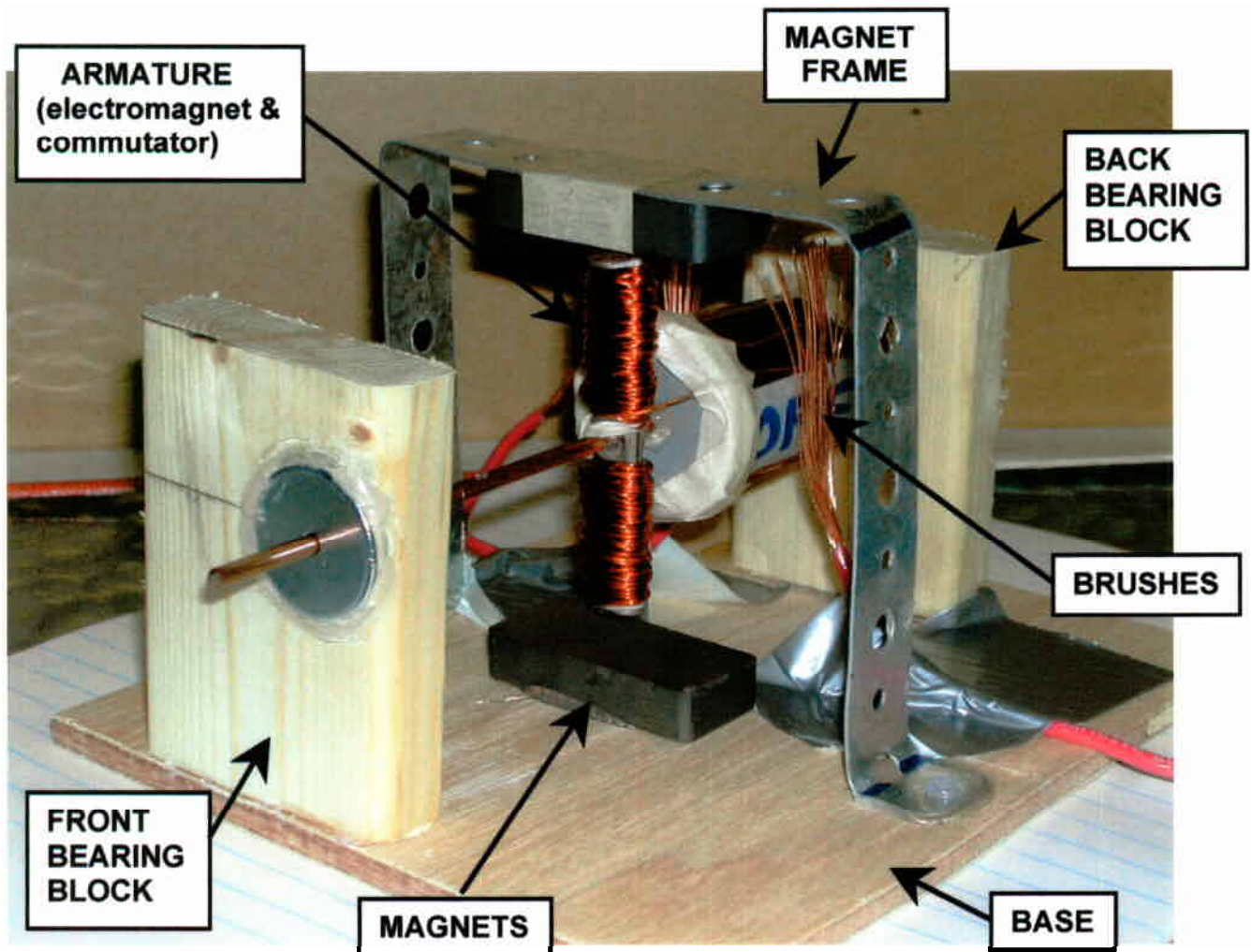
The brushes in a motor are attached to the battery and they are used to get electricity into the wire coil, turning it into an electromagnet. The 2 brushes rub against the commutator as it spins around. When the electromagnet's leads are touching the 2 brushes, electricity flows into and out of the wire coil, turning on the electromagnet. Whenever the brushes are touching the masking tape spaces – the “off spots” - no electricity can flow into the coil, and the electromagnet will be off.

- A) Cut 2 pieces of the stranded wire, each 8 in. long.
- B) On one end of each wire, strip off 1 in. of insulation, and twist the strands so they are tight. These ends of the brushes will be connected to the battery using the alligator clip test leads.
- C) On the other end of each wire, strip off 2 in. of insulation. Untwist the strands of wire until they are straight, and spread them out so they look like a flat paintbrush (see photo below).

### **Making the Brushes**

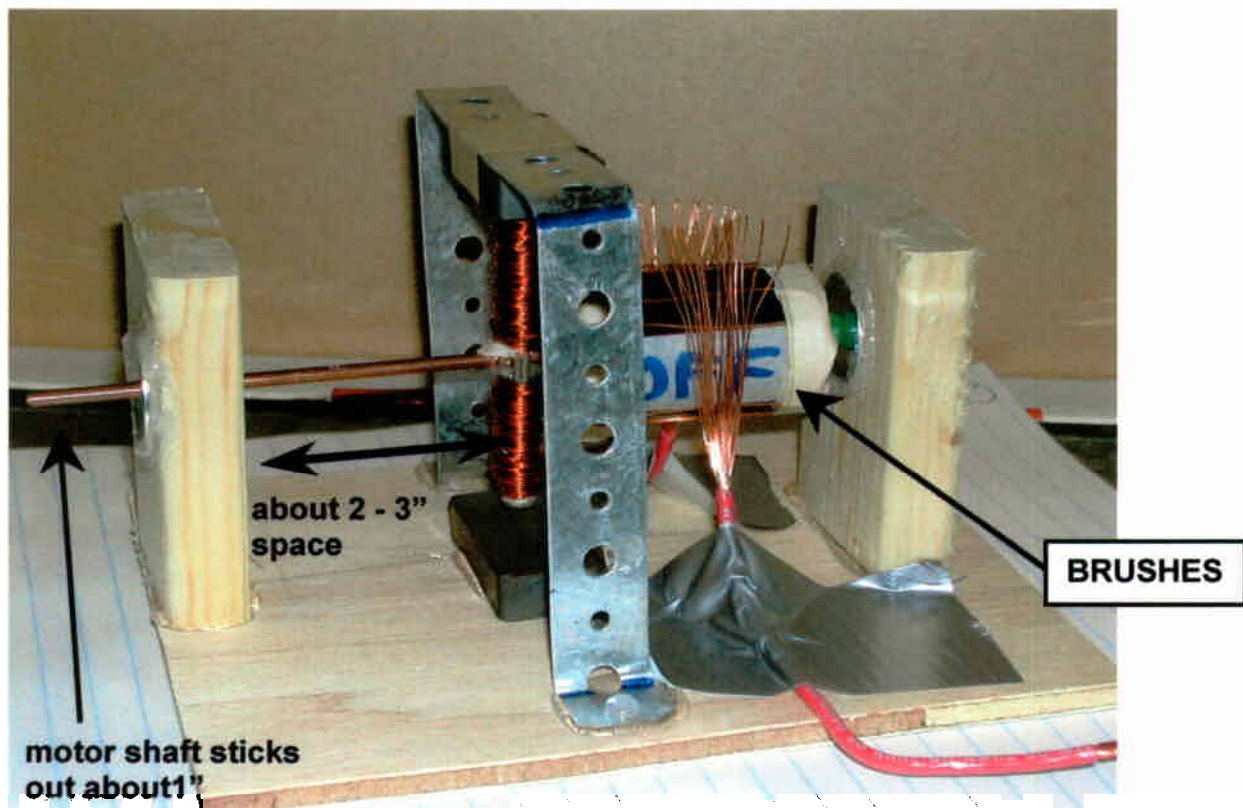


## STEP 6: Assembling Your Motor



- A) Place the front bearing block flush with (touching) one edge of your motor base, and place it so that the washer is about in the center of the base (see photo above). Hot glue in place.
- B) Slide the armature in place and also the back bearing block. Adjust the spacing of the bearing blocks so there is about 2 - 3" between the electromagnet and the front block, and so that the motor shaft sticks out of the front block by 1/2 - 1" (see photos above & below). **Make sure the armature spins freely and easily in the bearing blocks before gluing the other one down.** Outline the location of the back bearing block with a pencil, and then hot glue it in place (along with the armature inside the blocks).

- C) Place the magnet frame directly over the electromagnet and hot glue it to the base. Stick one magnet inside the top of the magnet frame, and hold the other magnet directly under the electromagnet. The gap between the electromagnet and the magnets should be  $1/8$ ". If the gap is too big, place some cardboard behind the magnets to make the gap as small as possible without hitting the electromagnet. **BE SURE TO PLACE THE 2 MAGNETS SO THEIR OPPOSITE POLES (N & S) ARE FACING EACH OTHER, OR YOUR MOTOR WILL NOT RUN!** Check this by lowering the top magnet straight onto the bottom magnet and be sure that they ATTRACT. Hot glue the magnets in place.
- D) Place the brushes on the left and right sides of the commutator (film canister with wires), so that they are touching the masking tape "off spots" (see photo below). The spread-out ends of the brushes should be above the top of the commutator and be pointing straight up. **The brushes must press gently against the commutator**, and remain in contact with the commutator as it spins. Tape the brushes to the base with duct tape.



E) Use the alligator clip test leads to connect the brushes to a 6-volt lantern or a 4 D-cell battery pack. Give the electromagnet a little flick, and your motor should start right up! If it doesn't, the first thing is to check to see if your magnets are facing the right way. BE PATIENT! It usually takes some "fiddling around" to make your motor work really well; but if you built it carefully, it will fly once you find the "hot spot" for the brushes. Try to bend the brushes and move them around slightly, changing their contact position and adjusting the pressure of the brushes against the commutator; if they press too hard, or if they do not make contact, the motor will not run.**Its even better if you untape the brushes and hold the them with your hands while the motor runs – then you will really get the feel for the best position and the right contact pressure – and your motor performance will be the best!**