How to Build a Fan like MacGyver
What you need

• Duct Tape
• White Out
• Sandpaper
• Nickel
• Scissors
• DC Motor Kit
  (inside foam cup)
Contents of the Kit

- Foam Cup
- Plastic Lid
- 6-meter wire
  - wrapped around plastic spool
  - insulated with red enamel
- 8-inch wire
  - The short wire
  - insulated with red enamel
- Rotor
- Putty
  - might be white or blue
About the Rotor

The rotor is the part of the motor that does the spinning.

The rotor has already been fabricated for you since it can take some time for the glue to dry.

Glue was applied to the head of each nail. Then the nails were pressed onto the craft magnets. Since the nails are made of iron, the magnetic force does a great job keeping the nails in place while the glue dries.
Step 1: Cut off bottom of cup.

The foam cup will be the structure of the motor. You will need to modify it in a few ways.

First, cut off the bottom two centimeters or so of the cup. That’s about an inch. Both the top and the bottom will be used later in the construction, so try to make one clean cut all the way around.

If you accidentally mangle your cup, please ask your TA for a replacement.
Step 2: Make holes for the rotor.

Make a mark on the cup that is about halfway between the two ends of the cup. Use the nail to punch a hole through this mark from the outside. This hole will be on the top of your motor.

Hold your cup so that the top of the motor (as defined by the hole) is horizontal. Use the nail to punch a second hole in the cup such that the rotor will be vertical when inserted into the holes.

This second hole will be a little bit closer to the drinking end of the cup as seen in the top photo.

*Make sure the rotor can spin with ease, like a top.* If the fit is too snug, the motor will not work. You will need to wiggle the rotor around to widen the holes a bit.
Notes on Removing Insulation

When removing insulation from the end of the wire, fold the sand paper and gently squeeze the wire between your thumb and forefinger. The wire should be a nice copper color underneath the insulation.

DO NOT press the wire against the table with the sand paper. This will scratch the tables.
Step 3: Wind the coil.

Remove the rotor from the cup.

Unwrap the long wire from the spool and wrap it around the cup, leaving about six inches of wire loose at the beginning and end of the coil.

You want your coil to be close to the holes that you have just punched, but you do not want the wire to cover the holes at all.

Use tape to secure the wire to the cup every few turns. Otherwise, the coil is likely to unravel or cover the holes.

Use the sand paper to remove the red insulation from the both ends of the long wire. Under the insulation, the wire will look like copper (because it’s copper).

This coil will be the electromagnet that will drive the rotor. All motors have an electromagnet somewhere. You have just completed the bulk of the “stator”, the part of the motor that does not rotate.
Step 4: Construct the base.

You will now make the base of the motor using the bottom of the cup. Cut out a rounded section from the base so that when the cup is placed on this support, the rotor is vertical (or close to it).

This may take a bit of tinkering to get it right. That’s what makes this fun, though, right?

Do not attach the motor to the base quite yet.
Step 5: Connect the nickel.

Before you attach the rest of the motor to the base, there is one very important thing you need to add.

Shave the insulation off of the last inch or so of each end of the SHORT wire using the sandpaper. This wire will sometimes be referred to as the nickel wire. (It is still made of copper.)

Create a good electrical connection between the nickel and the short wire. You can tape the short wire to Monticello, but make sure to the keep Thomas Jefferson uncovered.

Then, tape the nickel to the inside of the base with the short wire underneath still in good electrical contact. Leave as much of Thomas Jefferson uncovered as possible. The rotor will need to be able to make electrical contact to the nickel.
Step 6: Attach the base.

Now you can attach the base with some duct tape. Things should look something like this. The bottom of the rotor should be in contact with the nickel. If you move the rotor up and down you should be able to hear it “clink” on the nickel. **In addition to checking for the “clink”, check that the rotor spins with ease (like a top).**
Step 7: Quality Control

Warning: You are about to connect the battery to your motor’s coil of wire. If you leave the battery connected, the wire will get hot, and you can burn yourself. Please do not leave the coil connected directly to the battery for more than 2 seconds.

Briefly (for no more than 2 seconds) connect your battery across your coil to make sure that your rotor can turn under the influence of a magnetic field. (The rotor will not spin continuously, but you should see an angular displacement.)

If the rotor does not turn, make sure that you can spin it with your fingers like a top. You might need to wiggle the nails to expand the holes, as described in Step 2. If the rotor can spin like a top, but it does not turn when the battery is connected, it is possible that your battery is dead. See slide 20 (titled “Troubleshooting 2”) for instructions on how to test if the battery is dead.

Does the rotor turn when connected to the battery? Then it’s time for Synthesis Question 1.

Read and complete Synthesis Question 1
Step 7: Still Quality Control

You should notice that connecting the battery across the coil could never result in a spinning rotor. A constant magnetic field will not spin a bar magnet. We need to moderate the current in some way if we are to keep the rotor spinning.

To moderate the current, you will make the rotor part of the circuit. As the rotor spins, you will make it so that the circuit is broken and completed at just the right times to keep the rotor spinning.

Let’s make sure you understand how we can make the rotor part of the circuit.

1. Connect one end of the coil to the battery.
2. Connect the nickel wire to the other terminal of the battery.
3. Touch the free end of the coil to the bottom nail of the rotor. (Do not hold it there for more than 2 seconds!)

This should complete a circuit, turn on the current in the coils, and exert a torque on the rotor. Did you see the rotor turn when you completed the three steps above?

What we want is for the electrical connection to be broken just as the magnet is lining up with the field. This will allow it to keep spinning. Then, when the rotor gets just past where the magnet is lined up the opposite way, we want the circuit to be completed again so that a torque is once again exerted on the rotor. This takes just a little bit of MacGyvering.
Step 8: Apply white out to rotor.

Apply a thin but solid coat of white out to one half of the bottom nail of the rotor.

Please take a look carefully at the photo so that you do this correctly.

When the rotor is lain flat on the table, you should see a view like the one to the right. The dotted line is added for effect.

Covering less than half the nail is not good. Err on the side of too much white out.
Step 9: Situating the brush

Poke one end of the coil through the outside of the cup. Adjust it so that it makes firm contact with the bottom nail, either at the front or back of the nail.

Getting the wire in the right place works best when you take the rotor out first. Next, adjust the wire so that it is clearly too far toward the small opening. Finally, put the rotor back in place. The wire is often pressed up against the nail perfectly. If not, just try again.

Two possible top-down views. The thick lines represent the outline of the cup. The circle represents the nail. The thin line represents the brush. The brush should be in contact with the front or back of the nail.

Bad Ideas
The brush should touch the nail in the front or back, NOT in the manner shown here.
Also, DO NOT WRAP the wire around the nail. Remember, the idea is to alternately break and connect the circuit.
Step 9: Situating the brush

The wire that is in contact with the nail is called a “brush.”

In a motor a brush is an electrical contact between the rotor and the stator. You will find some kind of brush in most (but not all) motors.

When the brush is in contact with the nail, a current will flow in the circuit. When the brush contacts the white out (an insulator) the circuit will be broken.

The bottom nail, due to the way that it moderates the current flow in the circuit, could be called the “commutator.”
Before you power this thing up, it might be worth thinking about the motor as a circuit. This might be especially helpful if the motor doesn’t work immediately and you have to do some troubleshooting.
Step 10: Life

Warning: You are about to connect the motor to the battery. If the motor works and the rotor keeps spinning, you may leave the battery connected safely. This is because the current will be turning on and off. However, if the rotor stops, do not leave the battery connected as it might drain the battery.

Connect one terminal of the battery to the coil wire and one end of the battery to the nickel wire. Give the rotor a little spin. Does it work? If so, read the rest of this slide and then go to Step 11.

If the motor does not turn, the next slides have some troubleshooting tips.

As the motor runs, the brush and the nail tend to get a little oxidized (or burnt). This can cause the motor to slow down after it runs for awhile. With this in mind, it might not be wise to allow your motor to run for more than five or ten seconds at a time. If at any point you feel like you need to reinvigorate your motor, you can use the sandpaper to clean off the nail and the brush.

If the motor works, you can skip to Step 11 and complete your fan.
Troubleshooting 1

For the first 90 minutes of lab, the TA has been instructed to provide very little help. This experience will be more meaningful if you have to get things working on your own. Here are some common problems, starting with easy things to check and fix.

Possible Problem: The rotor is touching the tape, not the nickel
How to check it out: Can you make the rotor “clink” on the nickel? If not, you may have to rearrange the tape or scrape White Out off of the bottom tip of the nail.

Possible Problem: The rotor is too tight
How to check it out: Can you spin the rotor like a top? If not, there may be too much friction between the rotor and the cup. Gently wiggle the nail around in order to make the holes in the cup a little bigger.

Possible Problem: The brush is touching the nail in the wrong place
How to check it out: If you correctly applied White Out to the nail as shown in Step 8, then you must touch the brush to the nail either in the front or the back of the nail as shown in Step 9. Do not wrap the brush around the nail.

Possible Problem: There is not enough White Out on the rotor
How to check it out: Check that the White Out on your rotor looks like the figure in Step 8. You want slightly more than half of the rotor to be covered. If less than half of the rotor is covered, the circuit might stay connected for too long, slowing the rotor. You might need to apply more White Out.
Troubleshooting 2

Here are less common problems with slightly more involved fixes.

Possible Problem: The White Out has been applied to the wrong half of the rotor
How to check it out: Check that the White Out on your rotor looks like the figure in Step 8. If you rotated your White Out by 90 degrees, then the instructions regarding the brush won’t work. Shave off your White Out and apply a new coat according to Step 8.

Possible Problem: The battery is dead
How to check it out: Use the multimeter to measure the voltage produced by the batteries. If the voltage is much below 2.9 volts, alert your TA so that you can get new batteries.

Possible Problem: The electrical connections are bad
How to check it out: You might try “Step 7: Still Quality Control” again. If you don’t have any luck, use the multimeter to take some resistance measurements. The resistance setting is the first setting to the left of OFF. The bottom nail should be in good electrical contact with the nickel wire. Therefore, if you touch one lead of the multimeter to the bottom nail and the other lead of the multimeter to the nickel wire, the resistance should be just a few ohms. A reading of “O.L” indicates that there is a poor electrical connection. It may be necessary to reconnect the nickel wire to the nickel. See the Multimeter Instructions on the Reference page of the lab website for more details about using your multimeter to measure resistance.
Step 11: Make it a fan.

There are still two items in the kit that you haven’t used, which would be unacceptable to MacGyver. The putty and the lid will become the fan blade.

1. Take the lid and cut it into three slivers as shown above.
2. Take the middle sliver and poke a hole in the middle of it with a nail. Then make cuts along the (imaginary) dashed lines seen above. After that, fold upward along the (imaginary) dotted lines seen in the top-right photo.
3. Finally, attach the blade to the top of the rotor using the hole you poked and the putty. Enjoy the cool breeze!