HOW TO ASSEMBLE YOUR KIT

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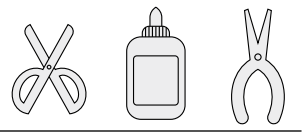
You Will Need:

- Scissors
- Wood Glue
- Needle-nose pliers



Read the other side of this page before you start!

1. Assemble the Stator

- Glue together the base, 3 bearings and 2 brush catch as shown (see figure 1). Set aside for the glue to dry.

2. Assemble the Rotor & Commutator

- Slide rotor hub sides onto the steel magnet core.
- Glue together all five wooden pieces of the rotor hub (see figure 2).
- Install the end caps onto the magnet core. Use glue.
- Glue together the four slotted commutator discs. Ensure proper alignment of the slots, per figure 3.
- Don't let the slots fill with hardened glue.
- Glue the commutator to the rotor hub, as shown in figure 4.

3. Install the Permanent Magnets

- Glue the wooden magnet caps to the outside of the stator as shown in figure 5.
- Glue the permanent magnets in the spaces under the caps.
- Ensure proper magnet orientation: Make sure you have one NORTH and one SOUTH pole facing toward the center of the motor. It does not matter which is which, so long as you have one of each. Set aside these parts for the glue to dry (see figure 5).

4. Wrap the Rotor Coils:

- Thread the magnet wire through any two opposite holes in the rotor hub, as shown in figure 6, until you reach the wire's midpoint.
- Wrap the wire around the steel core as shown in figure 7. It's important that you wrap the magnet wire in the right direction or the motor will not work. While looking at either end of the magnet core, wrap that side in a clockwise direction, then do exactly the same on the other side, also clockwise, while viewing the other end. Note that the direction of the spiral of wire does not reverse at the center/ hub. It spirals in the same direction, from one end of the core, all the way to the other.
- Wrap all of the wire, equal amounts on either side of the hub, leaving about 10 centimeters at each end.
- Thread the loose ends through any available small holes on the rotor hub to prevent the wire from coming unwound.
- Note: The copper wire in your kit looks bare, but it is coated with a thin, clear enamel insulation. Bare wire would not work .

5. Complete the Commutator.

- Using the copper sheet provided and a pair of scissors, cut out two copper strips, each 12 x 28 mm.
- Insert one short end of each copper strip into the slots in the commutator, as shown in figure 9.
- Bend the copper strips around the commutator so that the gaps between the copper strips align with rotor coils as shown in figure 9.
- Trim the ends of the rotor coil wires to about 2 cm.
- Strip the insulation from the ends of the wires using the sandpaper. Buff the copper strips to ensure good contact with the wires.
- Lay the bare ends of the wires against the copper strips, one wire per copper strip. It does not matter which wire contacts which copper strip. Press the commutator ring snugly over the copper and wires, all the way to the rotor hub (figures 10-11).
- Bend the ends of the wires back over the commutator ring & trim.

6. Install the Rotor Into the Stator

- Install the rotor into the stator as shown in figure 12, using the two included nails as rotor shafts.
- Don't forget the flywheel.

7. Install the Brushes (Paper Clips)

- Straighten both paperclips
- In each paper clip, bend a 90˚ angle about 30 mm from one end.
- Insert the straight end of each paper clip through the small holes in the inner bearing.
- Bend another 90˚angle in each paper clip, coplanar with the first bend, a few millimeters outside of the outer bearing.
- Tuck the outer ends of the paper clips into the notches in the Brush Spring Catch. See figure 13.
- Ensure that the brushes (paper clips) are touching the commutator, with a slight pressure keeping contact. Avoid excessive pressure. Bend and adjust the paper clips as necessary to keep light contact with the copper of the commutator.

8. Make it Go!

- Attach one terminal of a 9-Volt battery to each of the brushes. The motor may require a gentle kick-start with your finger to get it spinning.

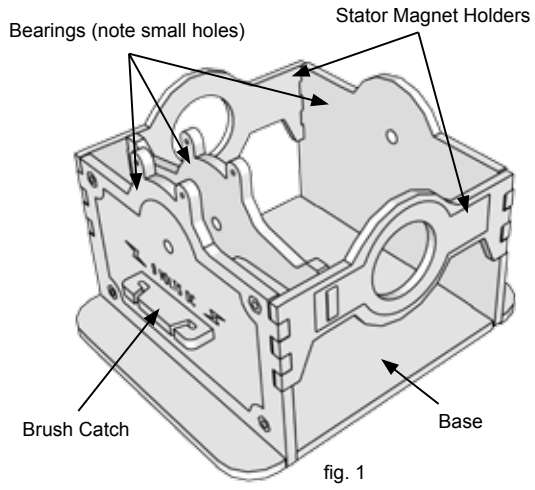


fig. 1

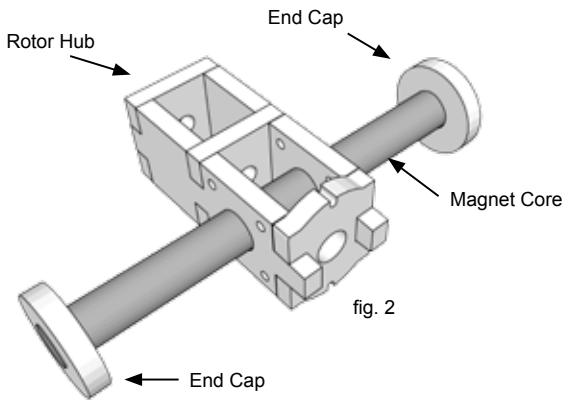


fig. 2

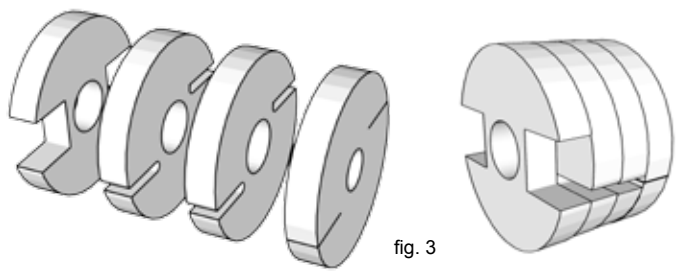


fig. 3

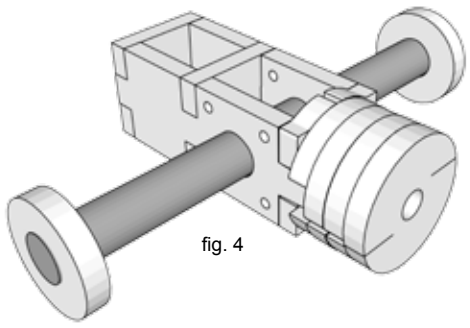


fig. 4

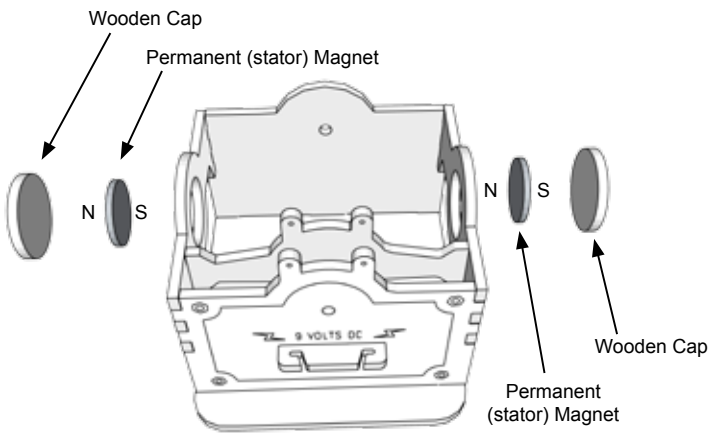


fig. 5

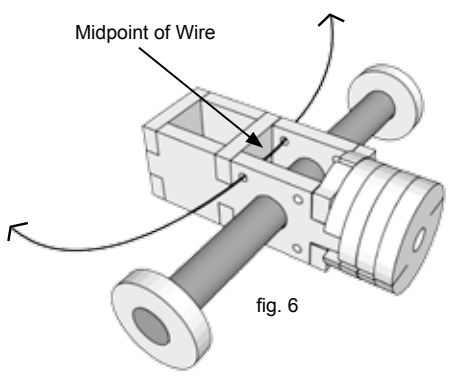
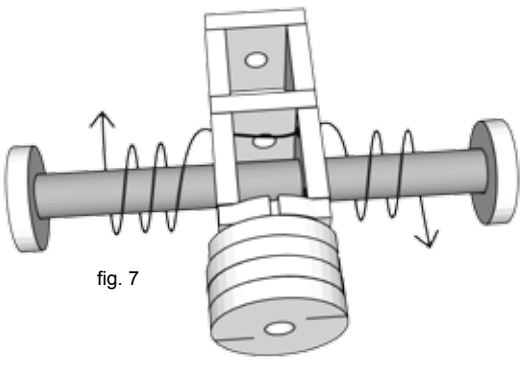


fig. 6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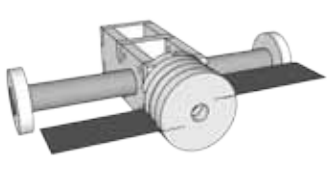
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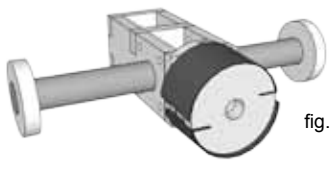
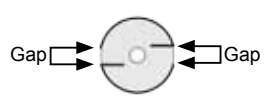


fig. 9



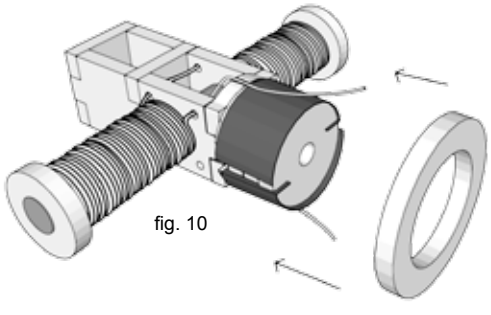


fig. 10

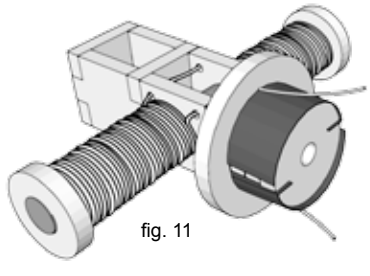


fig. 11

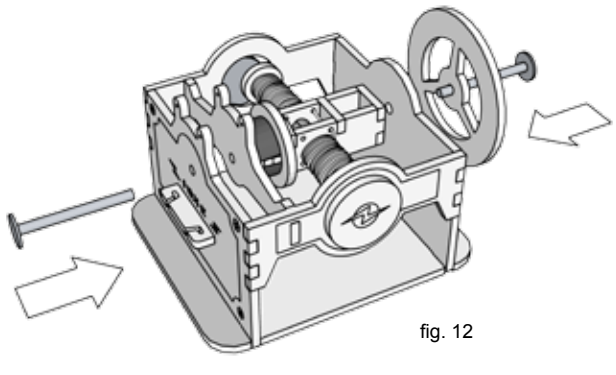


fig. 12

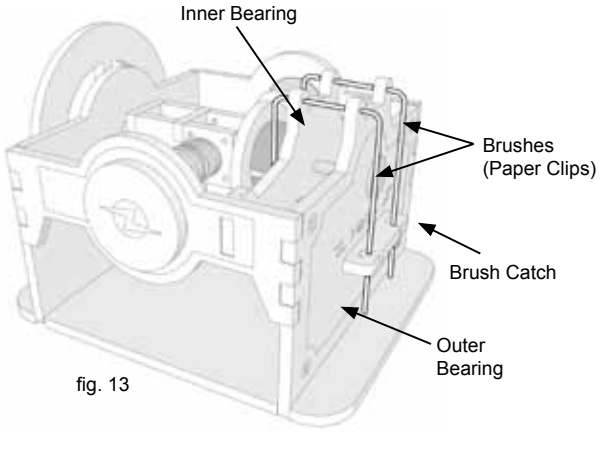


fig. 13

HOW IT WORKS & MORE INFO

More information, build photos and how-to videos at www.ImaginationHardware.com

Avoid These Simple Mistakes:

- Make sure your stator magnets are oriented correctly. The motor will not work if they are not installed correctly. See step 3 in the instructions.
- Pay careful attention to how you wind your rotor magnet coils. The motor will not work if the wire is coiled in the wrong direction. The copper wire should be wound as if in an single spiral around the entire core from end-to-end, even though there is a break in the middle for the hub. Do not accidentally reverse the direction of the wire. It is an easy mistake to make.
- Ensure that the rotor spins freely by hand. Don't allow the brushes (paper clips) or any other factors to introduce too much friction.
- Ensure good electrical contact at all critical points. Be sure to strip the insulation coating from the ends of the wire before sliding on the commutator slip ring. There must be electrical conductivity all the way from one brush, through the commutator, through the magnet coils, back out the commutator and out to the other brush. An open circuit anywhere will prevent the motor from working.
- Wood glue is recommended for all wood-to-wood joints, but it does not adhere well to metal. For wood-to metal contact, super glue is recommended.

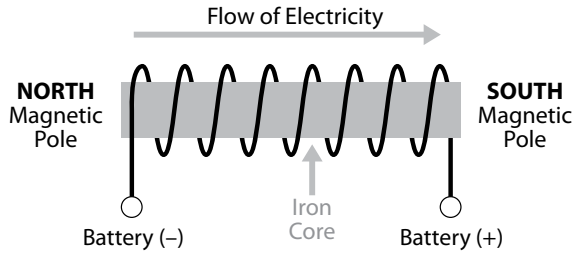
Who Cares, Anyway?

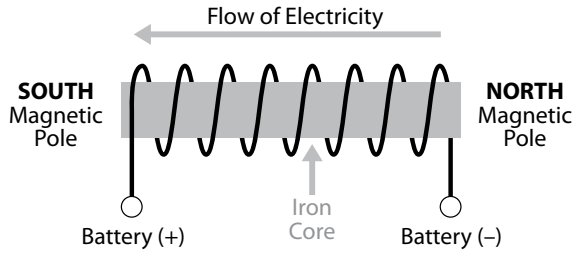
The electric motor changed civilization forever. We use them many times a day and don't even think about it. A few examples of the things we rely on every day: Water pumps, heaters, air conditioning, fans, refrigerators, hair dryers, clocks, CD and DVD players, computers, printers, garbage disposals, washing machines, clothes dryers, windshield wipers, fuel pumps, cell phones (the vibrator), drills, saws, sanders, air compressors and pumps all types. There probably isn't a house, car or office that doesn't have at least 20 electric motors in it - in most cases it's probably more than that. our lives would be very different without them, yet most people know nothing of how they work.

How a Motor Works - Background:

A DC motor appears complex, but it is a simple device, in principle. Let's start with some background information:

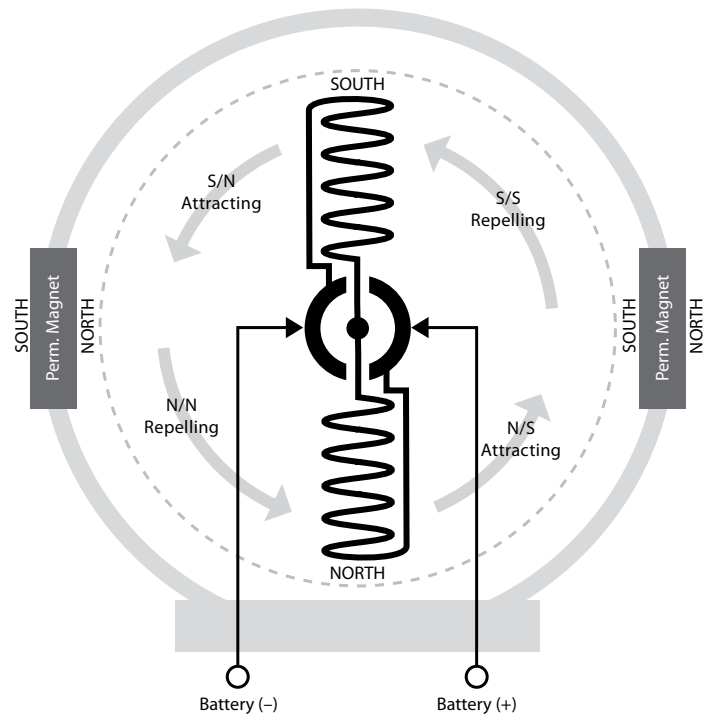
- This is a DC (Direct Current) motor. DC is a steady stream of electricity from negative to positive, as opposed to AC (Alternating Current), which switches direction back and forth very rapidly (60 times per second, in the US). Alternating Current circuits have no "positive" or "negative" sides, because they are constantly reversing. DC circuits (pretty much anything powered by a battery) has a "positive" and a "negative" side. AC motors work differently than DC motors.
- There are two types of magnets: Permanent magnets and electromagnets. A permanent magnet is always "on" - it always has a magnetic attraction to iron and other magnetic materials. An electromagnet is a magnet that is created by electric current flowing through a coil of wire. Electromagnets can be switched on and off.
- All magnets have a "north" and a "south" pole. Sometimes these are referred to as "positive" and "negative". With two magnets, similar poles repel each other and opposite poles attract. North repels other North poles. South repels other South poles. But North and South attract toward each other.
- A copper wire wrapped in a coil (around a pencil, for example) will turn into an electromagnet as soon as electricity flows through the wire. A copper wire wrapped around a piece of iron or steel (because steel is mostly iron) is a much stronger electromagnet. The iron "core" is activated by the coils magnetic field and the iron itself becomes a magnet, as long as there is electric current. An iron-core electromagnet can be ten thousand times stronger than an air-core electromagnet.
- An electromagnet has North and South poles, just like a permanent magnet. Which end is which is determined by two factors: in which direction the wire is wound (clockwise or counter clockwise around the core), and in which direction the electric current is flowing. Reversing either of these factors will switch the poles of the magnet so that North is where South used to be, and vice-versa. Switching BOTH factors would have no effect on the poles.





How Motors Work - the Fun Part:

- The outer housing, called the "stator" contains magnets. These can be permanent or electromagnets. It this kit, and most commercial DC motors, they are permanent magnets.
- The part of the motor that spins is called the "rotor". This consists of the main shaft and two or more electromagnets. Most motors have more than one, this kit has only one electromagnet because it is simpler to build that way.
- How do you get electricity to a spinning electromagnet? You can't just wire it in, it's spinning! Part of the rotor is the commutator. That's a slotted copper cylinder, which is electrically connected to the coils in the rotor's electromagnets.
- Springs in the stator hold electrical contacts against the commutator. These are called the "brushes". The brushes remain stationary as the rotor & commutator spin against them. The brushes are connected to the outside power source and transfer electrical power from the source to the spinning electromagnets through the commutator.
- The stator magnets in a motor are configured so that they are repelling the electromagnets in the rotor on one side, while they are attracting the electromagnets in the rotor on the other side. The negative magnetic fields on the stator repel the negative magnetic fields on the rotor and the positive magnetic fields of the stator repel the positive magnetic fields of the rotor. This causes the motor to spin.



- It looks as though North and South would come together and the motor would get stuck after only half of one revolution, but just as they are about to come together, the flow of electricity in the rotor coils is reversed because the commutator has flipped, and reversed contact with the brushes. So the North and South poles of the rotor reverse, and the whole cycle starts over again! The rotor's momentum ensures that the motor keeps spinning during the brief moment that the magnetic field is switching.