

How Electric Motors Work

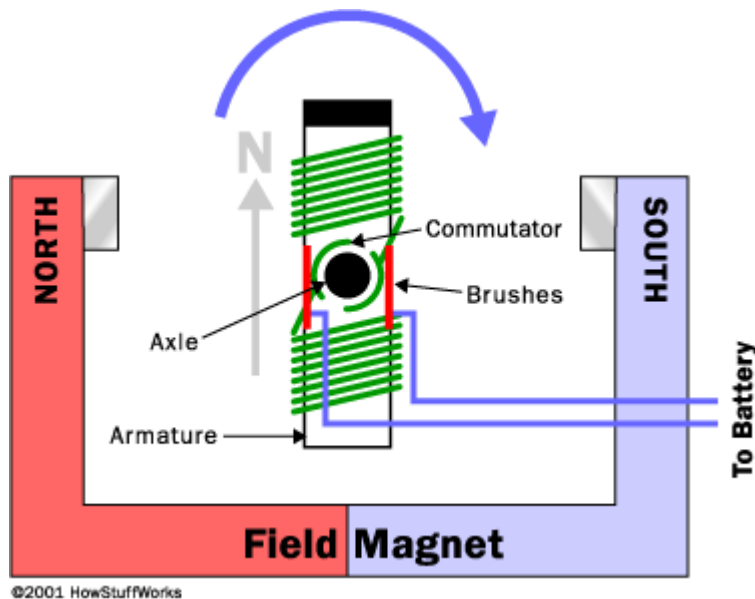
by [Marshall Brain](#)

Introduction to How Electric Motors Work

Electric motors are everywhere! In your house, almost every mechanical movement that you see around you is caused by an AC (alternating current) or DC (direct current) electric motor.

A simple motor has six parts: **Armature or rotor, Commutator, Brushes, Axle, Field magnet, DC power supply of some sort**

By understanding how a motor works you can learn a lot about magnets, electromagnets and electricity in general. In this article, you will learn what makes electric motors tick.



Inside an Electric Motor

An electric motor is all about magnets and magnetism: A motor uses **magnets** to create motion. If you have ever played with magnets you know about the fundamental law of all magnets: Opposites attract and likes repel. So if you have two bar magnets with their ends marked "north" and "south," then the north end of one magnet will attract the south end of the other. On the other hand, the north end of one magnet will repel the north end of the other (and similarly, south will repel south). Inside an electric motor, these attracting and repelling forces create **rotational motion**.

In the above diagram, you can see two magnets in the motor: The armature (or rotor) is an electromagnet, while the field magnet is a permanent magnet (the field magnet could be an [electromagnet](#) as well, but in most small motors it isn't in order to save power).

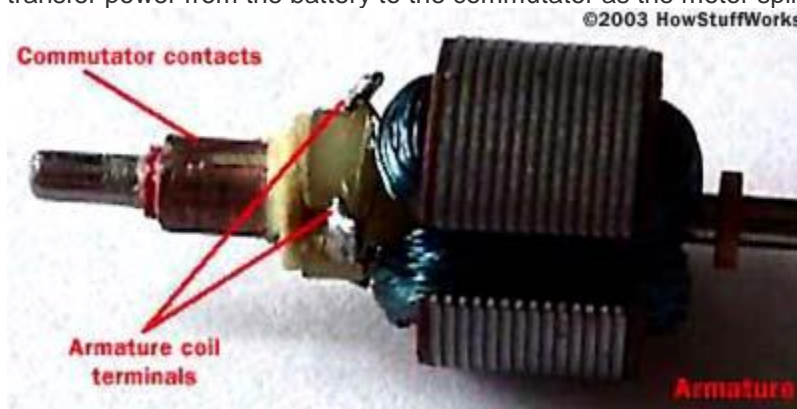


Toy Motor

The motor being dissected here is a simple electric motor that you would typically find in a toy.

You can see that this is a small motor, about as big around as a dime. From the outside you can see the steel can that forms the body of the motor, an axle, a nylon end cap and two [battery](#) leads. If you hook the battery leads of the motor up to a flashlight battery, the axle will spin. If you reverse the leads, it will spin in the opposite direction. Here are two other views of the same motor. (Note the two slots in the side of the steel can in the second shot -- their purpose will become more evident in a moment.)

The nylon end cap is held in place by two tabs that are part of the steel can. By bending the tabs back, you can free the end cap and remove it. Inside the end cap are the motor's brushes. These brushes transfer power from the battery to the commutator as the motor spins:



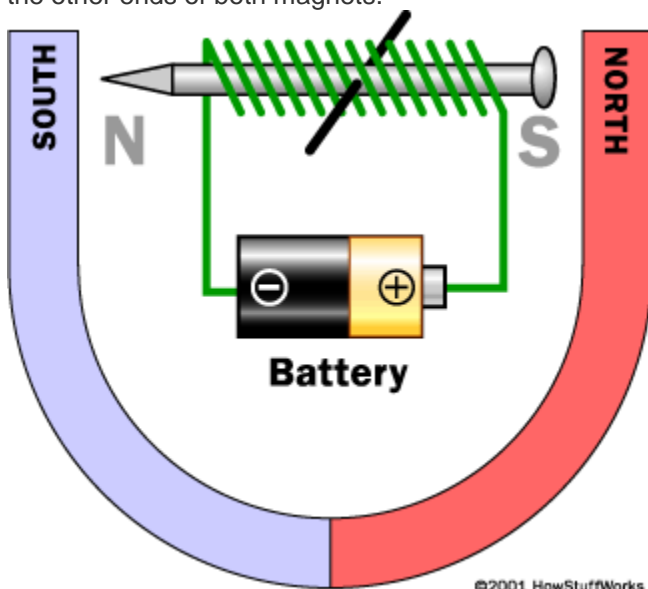
More Motor Parts

The axle holds the armature and the commutator. The armature is a set of [electromagnets](#), in this case three. The armature in this motor is a set of thin metal plates stacked together, with thin copper wire coiled around each of the three poles of the armature. The two ends of each wire (one wire for each pole)

are soldered onto a terminal, and then each of the three terminals is wired to one plate of the commutator.

The final piece of any DC electric motor is the field magnet. The field magnet in this motor is formed by the can itself plus two curved permanent magnets.

One end of each magnet rests against a slot cut into the can, and then the retaining clip presses against the other ends of both magnets.



Electromagnet in a horseshoe magnet

Electromagnets and Motors

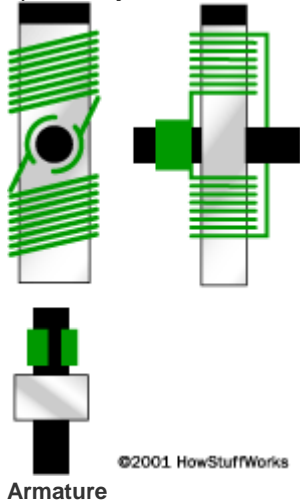
To understand how an electric motor works, the key is to understand how the [electromagnet](#) works. (See [How Electromagnets Work](#) for complete details.)

An electromagnet is the basis of an electric motor. You can understand how things work in the motor by imagining the following scenario. Say that you created a simple electromagnet by wrapping 100 loops of wire around a nail and connecting it to a [battery](#). The nail would become a magnet and have a north and south pole while the battery is connected.

Now say that you take your nail electromagnet, run an axle through the middle of it and suspend it in the middle of a horseshoe magnet as shown in the figure below. If you were to attach a battery to the electromagnet so that the north end of the nail appeared as shown, the basic law of magnetism tells you what would happen: The north end of the electromagnet would be repelled from the north end of the horseshoe magnet and attracted to the south end of the horseshoe magnet. The south end of the electromagnet would be repelled in a similar way. The nail would move about half a turn and then stop in the position shown.

You can see that this half-turn of motion is simply due to the way magnets naturally attract and repel one another. The key to an electric motor is to then go one step further so that, at the moment that this half-

turn of motion completes, the field of the electromagnet **flips**. The flip causes the electromagnet to complete another half-turn of motion. You flip the magnetic field just by changing the direction of the electrons flowing in the wire (you do that by flipping the battery over). If the field of the electromagnet were flipped at precisely the right moment at the end of each half-turn of motion, the electric motor would spin freely.

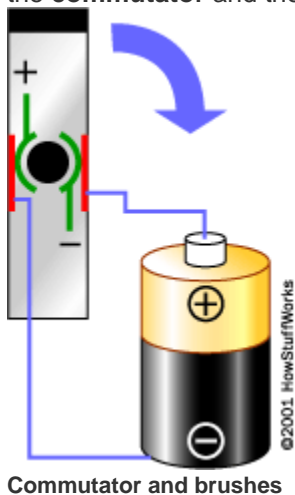


Armature, Commutator and Brushes

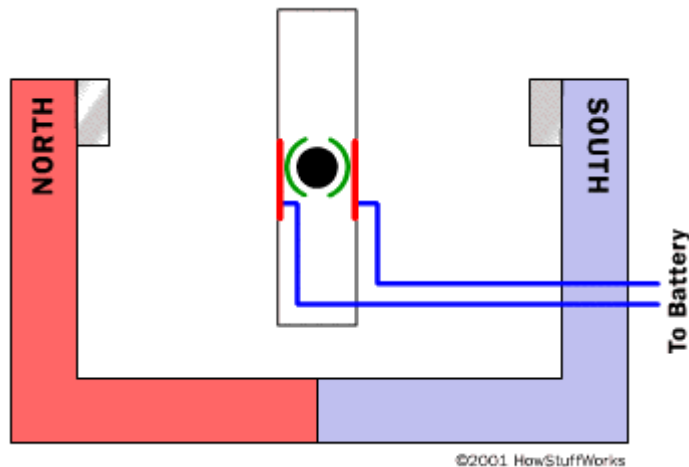
Consider the image on the previous page. The **armature** takes the place of the nail in an electric motor. The armature is an electromagnet made by coiling thin wire around two or more poles of a metal core.

The armature has an **axle**, and the commutator is attached to the axle. In the diagram to the right, you can see three different views of the same armature: front, side and end-on. In the end-on view, the winding is eliminated to make the commutator more obvious. You can see that the commutator is simply a pair of plates attached to the axle. These plates provide the two connections for the coil of the electromagnet.

The "flipping the electric field" part of an electric motor is accomplished by two parts: the **commutator** and the **brushes**.



The diagram at the right shows how the commutator and brushes work together to let current flow to the electromagnet, and also to flip the direction that the electrons are flowing at just the right moment. The contacts of the commutator are attached to the axle of the electromagnet, so they spin with the magnet. The brushes are just two pieces of springy metal or carbon that make contact with the contacts of the commutator.



Armature

Putting It All Together

When you put all of these parts together, what you have is a complete electric motor:

In this figure, the armature winding has been left out so that it is easier to see the commutator in action. The key thing to notice is that as the armature passes through the horizontal position, the poles of the electromagnet flip. Because of the flip, the north pole of the electromagnet is always above the axle so it can repel the field magnet's north pole and attract the field magnet's south pole.

If you ever have the chance to take apart a small electric motor, you will find that it contains the same pieces described above: two small permanent magnets, a commutator, two brushes, and an electromagnet made by winding wire around a piece of metal. Almost always, however, the rotor will have **three poles** rather than the two poles as shown in this article. There are two good reasons for a motor to have three poles:

- It causes the motor to have better dynamics. In a two-pole motor, if the electromagnet is at the balance point, perfectly horizontal between the two poles of the field magnet when the motor starts, you can imagine the armature getting "stuck" there. That never happens in a three-pole motor.
- Each time the commutator hits the point where it flips the field in a two-pole motor, the commutator shorts out the battery (directly connects the positive and negative terminals) for a moment. This shorting wastes energy and drains the battery needlessly. A three-pole motor solves this problem as well.

It is possible to have any number of poles, depending on the size of the motor and the specific application it is being used in.