Electric Motors

By Chris Woodford

Updated: May 30, 2014

Name _________________________ Date _____________ *Student Common Core Reading*

Flick a switch and get instant power—how our ancestors would have loved electric motors! You can find them in everything from electric trains to remote-controlled cars—and you might be surprised how common they are. How many electric motors are there in the room with you right now? There are probably two in your computer for starters, one spinning your hard drive around and another one powering the cooling fan. If you're sitting in a bedroom, you'll find motors in hair dryers and many toys; in the bathroom, they're in extractor fans, and electric shavers; in the kitchen, motors are in just about every appliance from clothes washing machines and dishwashers to coffee grinders, microwaves, and electric can openers. Electric motors have proved themselves to be among the greatest inventions of all time. Even small electric motors are surprisingly heavy. That's because they're packed with tightly wound copper and heavy magnets. Let's pull some apart and find out how they work!

Photo: This is the motor from an old electric lawn mower. The copper-colored thing toward the front of the axle, with slits cut into it, is the commutator that keeps the motor spinning in the same direction.

Electricity, magnetism, and movement

The basic idea of an electric motor is really simple: you put electricity into it at one end and an axle (metal rod) rotates at the other end giving you the power to drive a machine of some kind. How does this work in practice? Exactly how do your convert electricity into movement? To find the answer to that, we have to go back in time almost 200 years.

Suppose you take a length of ordinary wire, make it into a big loop, and lay it between the poles of a powerful, permanent horseshoe magnet. Now if you connect the two ends of the wire to a battery, the wire will jump up briefly. It's amazing when you see this for the first time. It's just like magic! But there's a perfectly scientific explanation. When an electric current starts to creep along a wire, it creates a magnetic field all around it. If you place the wire near a permanent magnet, this temporary magnetic field interacts with the permanent magnet's field. You'll know that two magnets placed near one another either attract or repel. In the same way, the temporary magnetism around the wire attracts or repels the permanent magnetism from the magnet, and that's what causes the wire to jump.

Why are electricmotors packed with magnets and tightly wound wires?

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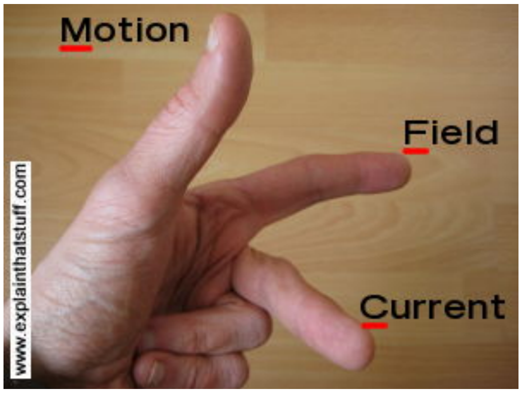
Fleming's Left-Hand Rule



You can figure out the direction in which the wire will jump using a handy mnemonic (memory aid) called Fleming's Left-Hand Rule (sometimes called the Motor Rule).

Hold out the thumb, first finger, and se**C**ond finger of your left hand so all three are at right angles. If you point the second finger in the direction of the **C**urrent (which flows from the positive to the negative terminal of the battery), and the **F**irst finger in the direction of the **F**ield (which flows from the North to the South Pole of the magnet), your thu**M**b will show the direction in which the wire **M**oves.

That's...

- **F**irst finger = **F**ield
- Se**C**ond finger = **C**urrent
- Thu**M**b = **M**otion

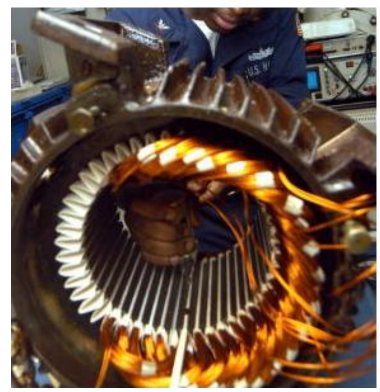


Photo by Jason Jacobowitz courtesy of US Navy.

How an electric motor works—in theory

In the photo, an electrician repairs an electric motor onboard an aircraft carrier. The shiny metal he's using may look like gold, but it's actually copper, a significantly better conductor that is much less expensive.

The link between electricity, magnetism, and movement was originally discovered in 1820 by French physicist André-Marie Ampère (1775–1867) and this is the basic science behind an electric motor. But if we want to turn this amazing scientific discovery into a more practical bit of technology to power our electric mowers and toothbrushes, we've got to take this technology a little bit further. The inventors who did that were Englishmen Michael Faraday (1791–1867) and William Sturgeon (1783–1850) and American Joseph Henry (1797–1878). Here's how they arrived at their brilliant invention.

Because the current flows in opposite directions in the wires, Fleming's Left-Hand Rule tells us the two wires will move in opposite directions. In other words, when we switch on the electricity, one of the wires will move upward and the other will move downward.

If the coil of wire could carry on moving like this, it would rotate continuously—and we'd be well on the way to making an electric motor. But that can't happen with our present setup: the wires will quickly tangle up. Not only that, but if the coil could rotate far enough, something else would happen. Once the coil reached the vertical position, it would flip over, so the electric current would be flowing through it the opposite way. Now the forces on each side of the coil would reverse. Instead of rotating continuously in the same direction, it would move back in the direction it had just come! Imagine an electric train with a motor like this: it would keep shuffling back and forward on the spot without ever actually going anywhere.

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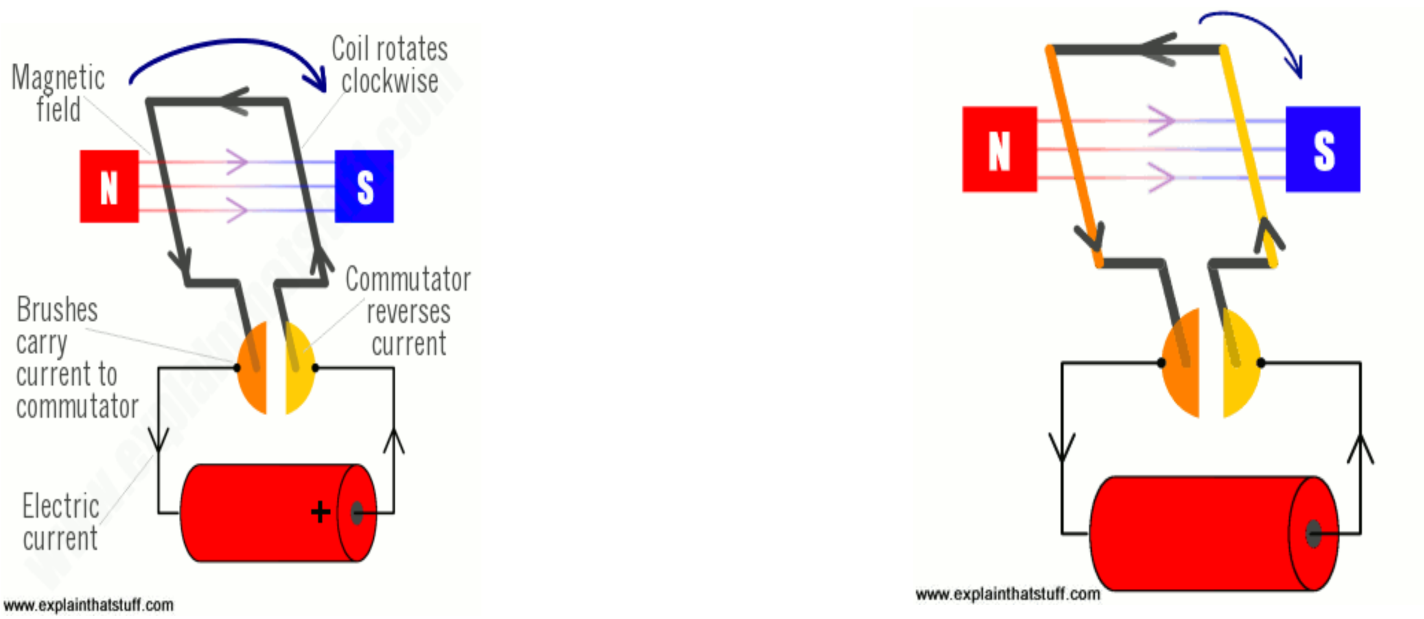
How an electric motor works—in practice

There are two ways to overcome this problem. One is to use a kind of electric current that periodically reverses direction, which is known as an alternating current (AC). In the kind of small, battery-powered motors we use around the home, a better solution is to add a component called a commutator to the ends of the coil. (Don't worry about the meaningless technical name: this slightly old-fashioned word "commutation" is a bit like the word "commute". It simply means to change back and forth in the same way that commute means to travel back and forth.) In its simplest form, the commutator is a metal ring divided into two separate halves and its job is to reverse the electric current in the coil each time the coil rotates through half a turn. One end of the coil is attached to each half of the commutator. The electric current from the battery connects to the motor's electric terminals. These feed electric power into the commutator through a pair of loose connectors called brushes, made either from pieces of graphite (soft carbon similar to pencil "lead") or thin lengths of springy metal, which (as the name suggests) "brush" against the commutator. With the commutator in place, when electricity flows through the circuit, the coil will rotate continually in the same direction.



Left: A simplified diagram of the parts in an electric motor. Right: How it works in practice. Note how the commutator reverses the current each time the coil turns halfway. This means the force on each side of the coil is always pushing in the same direction, which keeps the coil rotating

A simple, experimental motor such as this isn't capable of making much power. We can increase the turning force (or torque) that the motor can create in three ways: either we can have a more powerful permanent magnet, or we can increase the electric current flowing through the wire, or we can make the coil so it has many "turns" (loops) of very thin wire instead of one "turn" of thick wire. In practice, a motor also has the permanent magnet curved in a circular shape so it almost touches the coil of wire that rotates inside it. The closer together the magnet and the coil, the greater the force the motor can produce.

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List the 3 ways that torque can be increased in a motor and explain how each one would work

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Inside a typical motor

Although we've described a number of different parts, you can think of a motor as having just two essential components:

- There's a permanent magnet (or magnets) around the edge of the motor case that remains static, so it's called the stator of a motor.
- Inside the stator, there's the coil, mounted on an axle that spins around at high speed—and this is called the rotor. The rotor also includes the commutator.

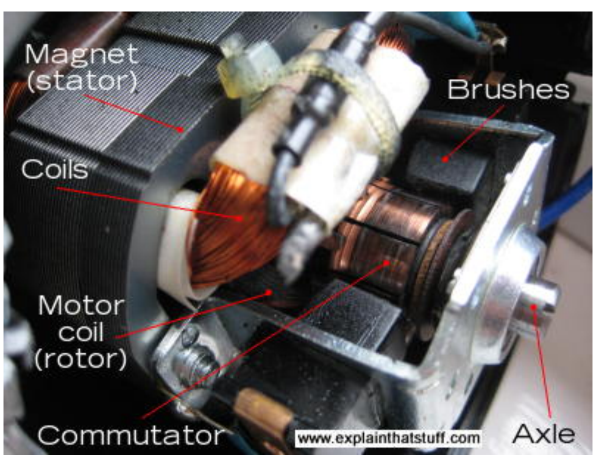

Photo: The main parts inside a medium-sized electric motor from a coffee grinder. The gray magnet round the edge is the stator. The orange-colored coils shown here link to the actual rotating coil inside the magnet (which I've marked, but isn't clearly visible). Note also the slits in the commutator and the carbon brushes pushing against it. Motors in such things as electric railroad trains are many times bigger and more powerful than this, but essentially work the same way.

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Other kinds of electric motors

In ordinary DC motors, like the ones we've just considered, the rotor spins inside the stator. AC motors work a slightly different way: they pass alternating current through opposing pairs of magnets to create a rotating magnetic field, which "induces" (creates) a magnetic field in the motor's rotor, causing it to spin around. If you take one of these induction motors and "unwrap" it, so the stator is effectively laid out into a long continuous track, the rotor can roll along it in a straight line. This ingenious design is known as a linear motor, and you'll find it in such things as factory machines and floating "maglev" (magnetic levitation) railroads.

Another interesting design is the brushless DC (BLDC) motor. The stator and rotor effectively swap over, with multiple iron coils static at the center and the permanent magnet rotating around them, and the commutator and brushes are replaced by an electronic circuit. You can read more in our main article on hub motors. Stepper motors, which turn around through precisely controlled angles, are a variation of brushless DC motors.

Explain the differences between AC and DC Motors and say where an AC Motor might be used.

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Adapted from: http://www.explainthatstuff.com/electricmotors.html
Extension: "Electromotors in Cells" - news article: http://www.sciencemag.org/content/308/5722/642

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