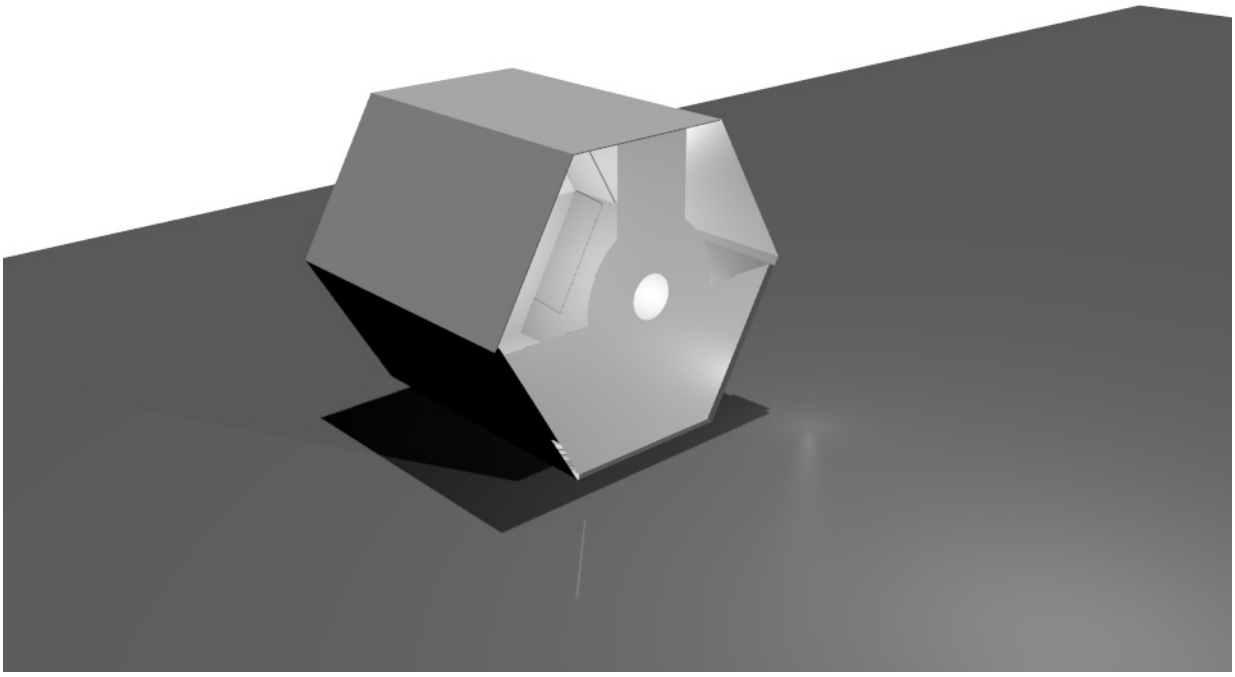
The Papercraft DC Motor by Jason Bennett



Introduction

Humans since the dawn of human time have used the forces of nature to create tools that greatly amplify our natural capacities. A water buffalo may be larger and stronger than a human, but is it larger and stronger than a bulldozer? A cheetah may be fast, but is it faster than a Tesla Roadster? The human capacity to build tools that use natural forces has given us a significant advantage over other animals. It has also given us great responsibility to understand and use our tools for worthwhile purposes.

Humans invent even when we don't fully understand our inventions. If it were true that humans needed to understand every fundamental principle behind an invention, we'd never invent anything! Even today physicsists struggle to understand the fundamental forces in our universe, and yet we are still able to use gravity, electromagnetism, and the nuclear forces to build tools that are immensely powerful. These tools help us work and help us understand how nature works.

Sometimes you will know how something works before you build it, and sometimes you will build something before you know how it works. Inventing and understanding are activities of discovery that complement each other.

Using this kit you will build a working direct current (DC) electric motor. And then, using your brain, you will figure out how it works!

What You Will Need

This booklet assumes you are building from the provided kit.

It is possible to build the entire motor from scratch. If you would prefer to do it this way, please visit the companion website at www.jasonbennett.name/dcmotor

Imagining Magnetic Attraction

Take two magnets and stick them together. What do you think is happening here? Write your answer in a short paragraph below. Be sure to use complete sentences. Feel free to illustrate your ideas as well.

Imagining Magnetic Repulsion

Take two magnets and force them to repel each other. How did you make this happen? Knowing that magnets can attract and repel, what do you think this new information indicates about magnets? Write your answer in a short paragraph below. Feel free to illustrate your ideas as well.

Imagining Magnetic Fields

Place your magnets below this book so that they form a bridge like this:

Now place a sheet of white paper on top of this book.

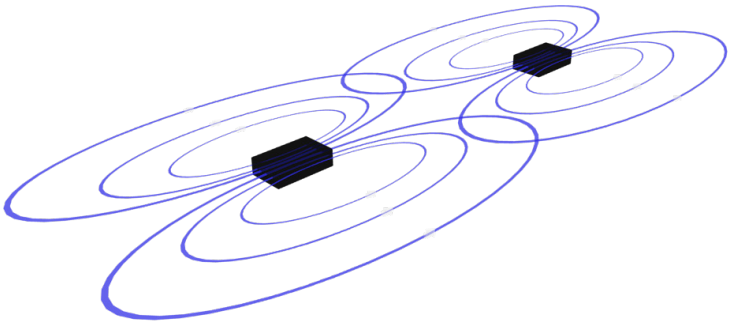
Sprinkle iron filings on top of the sheet, being sure to spread them around evenly.

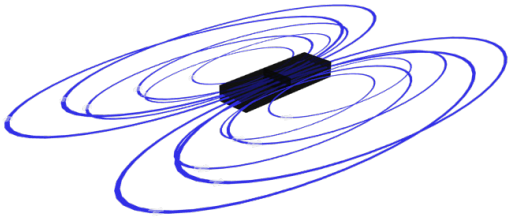
Draw what you see in the area below.

Imagining Magnetic Fields

Magnets Explained

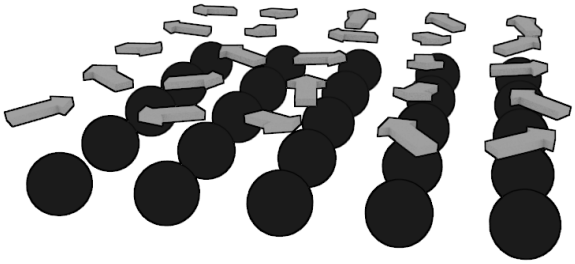
As you saw in the iron filings, the magnets produce magnetic fields. When these fields align, the magnets attract, when they oppose, the magnets repel.



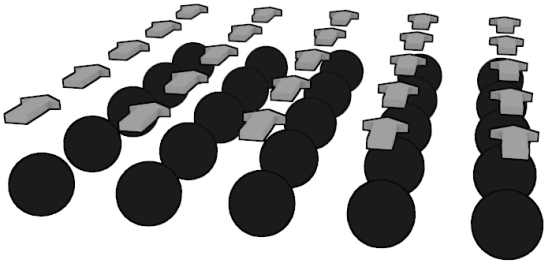


Magnetism at the Atomic Level

Magnetic fields is a result of electron spin aligning in a particular direction in the atoms of an element.



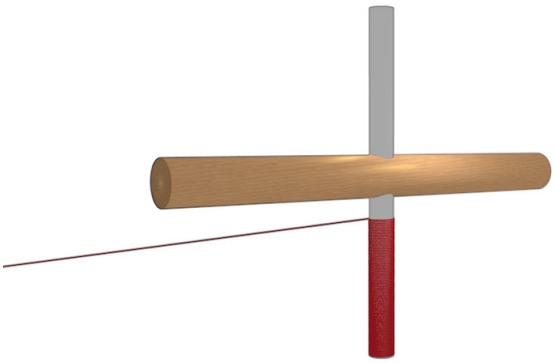
Without alignment, a strong magnetic field will not exist.



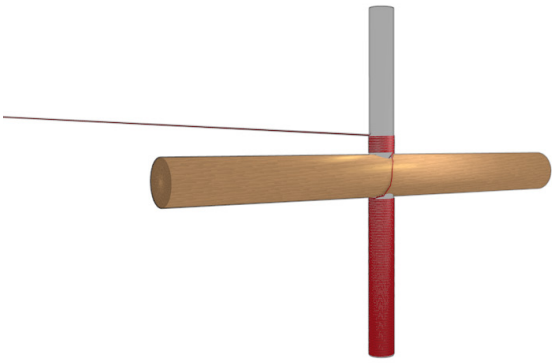
When aligned, a strong magnetic field will exist. Some elements (such as Iron) have more electrons available to align.

Building the Electromagnet

Follow these steps to build the electromagnet.



Be sure to wrap the wire in the same direction on both sides. If you start clockwise, continue clockwise when you wrap over to the second side.



Testing and Imagining the Electromagnet

Using matches or a lighter, burn off some of the insulation from either end of the electromagnet wire.

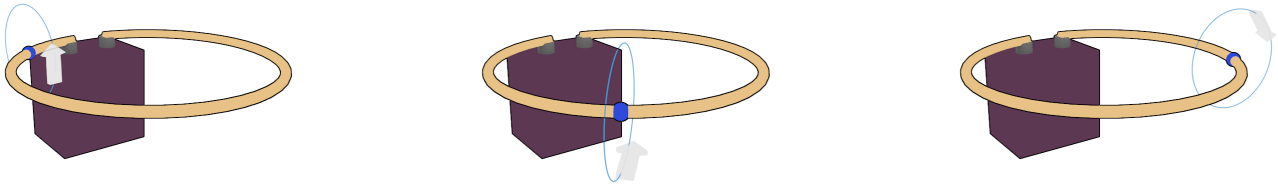
Attach each wire end to a terminal on the battery.

Now try picking up a paper clip or anything metallic. Disconnect the alligator clips and reattach them to engage and disengage the electromagnet.

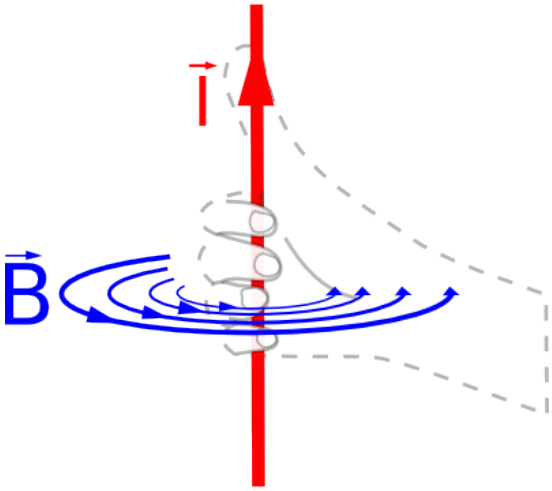
Try putting your electromagnet under this book and turning it on, then sprinkling some iron filings on top of a piece of paper resting on top of the book. Why do you think this is happening? Answer below in a short paragraph. Be sure to use complete sentences. Feel free to illustrate your work.

Electromagnetism Explained

When you connect a conductor such as copper wire to a battery, electrons move through the conductor. The magnetic fields of these electrons move with it, perpendicular to its motion. The magnetic field polarity is always counter-clockwise to the direction of motion.



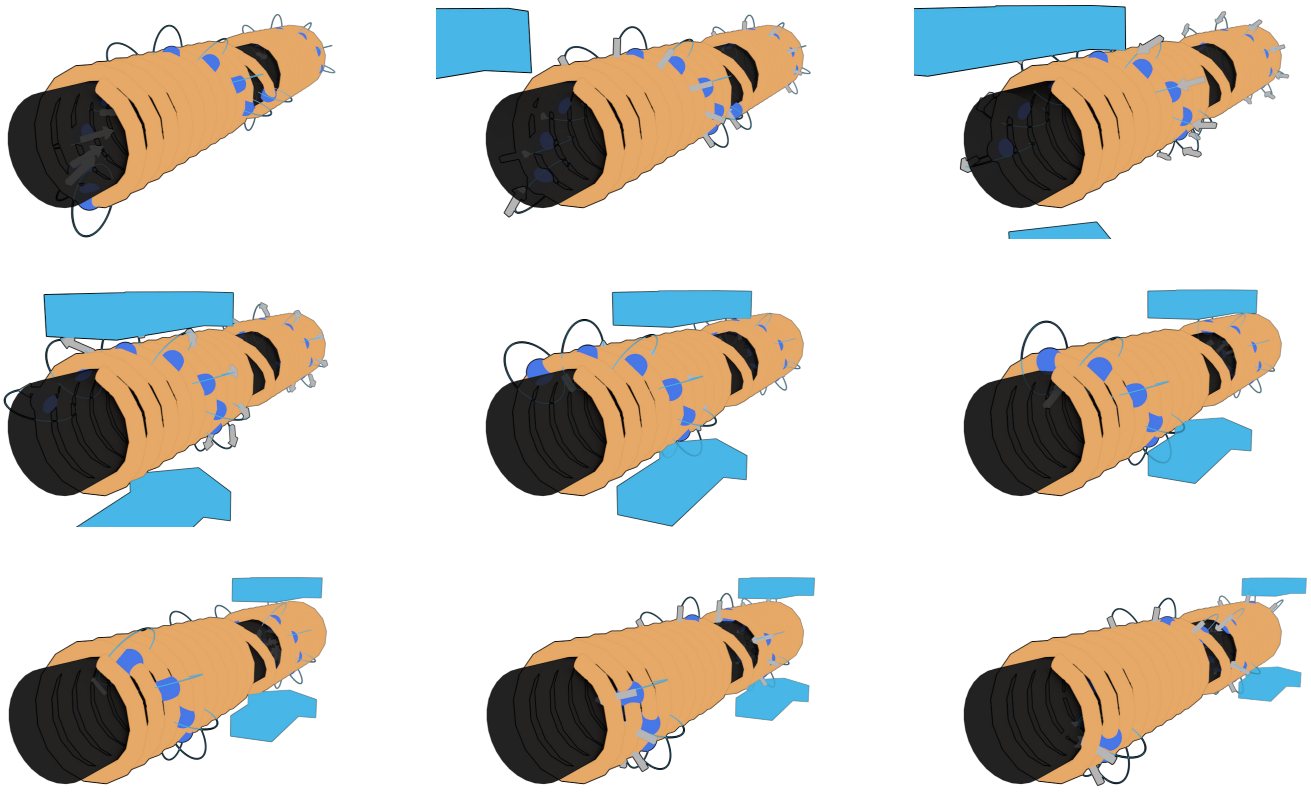
This principle is summarized in physics as the "Right Hand Rule". By sticking out your thumb and curling your fingers around it, you can easily remember the polarity of a electron's magnetic field in a current. The thumb is the direction of current (always from negative to positive on a battery), and the fingers are the polarity of the field.



Why does this happen? It's a very complicated answer that requires an understanding of Einstein's Special Theory of Relativity. Some day your curiosity may lead you to learn more, but for now it's enough to know that this is how it is. We don't always need to know everything about natural laws before using them to invent.

Electromagnetism Explained

When you wrap an insulated conductor around a core made of a material that is easily magnetized (such as Iron), the electrons whiz around the spiral, bringing their magnetic fields with them. The sum total of all these magnetic fields magnetizes the inner core material, producing a strong electromagnet.

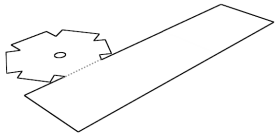


This is why we had to make sure the wire wrapped all in the same direction-- so that our magnetic field polarity is only pointing one way.

Out of curiosity, what do you think would happen if we used uninsulated copper wire instead?

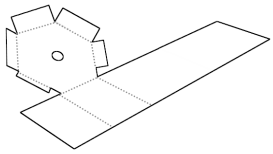
The DC Motor: Building the Frame

1



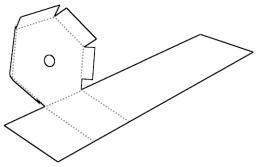
Step 1: lay the largest piece out flat.

1



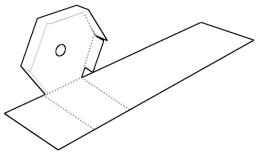
Step 2: fold in the tabs and the hexagon.

1



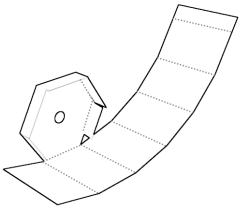
Step 3

1



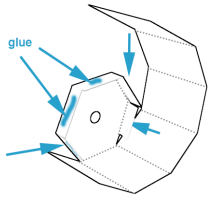
Step 4

1



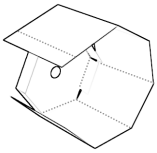
Step 5: Curl the sides around the outside.

1



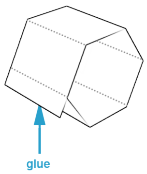
Step 6: Glue the sides to the tabs.

1



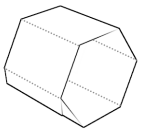
Step 7: Ensure a good fit!

1



Step 8: Glue the last tab to close it.

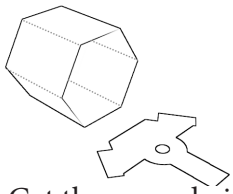
1



Step 9

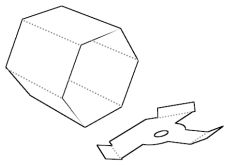
The DC Motor: Building the Frame

1



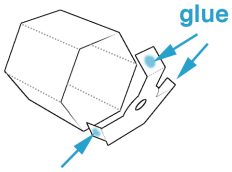
Step 10: Get the second piece.

1



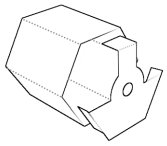
Step 11: Fold up the tabs.

1



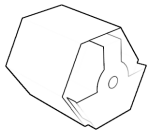
Step 12: Glue the outside of the tabs.

1



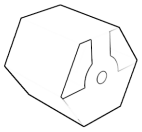
Step 13: Fit into the large piece.

1

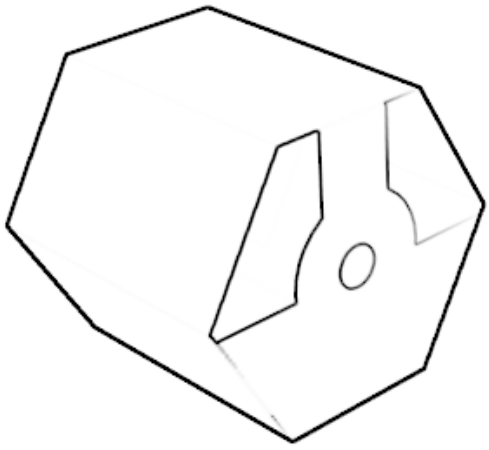


Step 14: Ensure a tight fit!

1

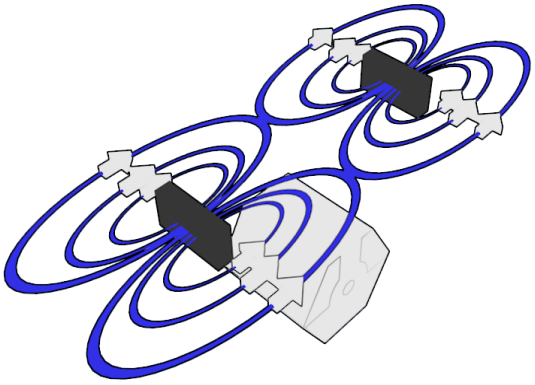


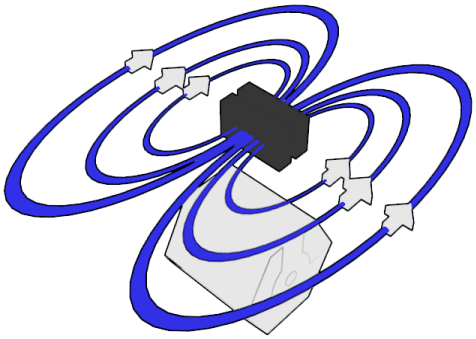
You're done!



Attaching the Magnets

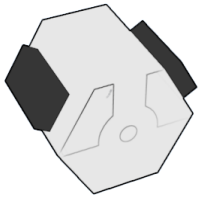
Align the magnets so they are attracting.

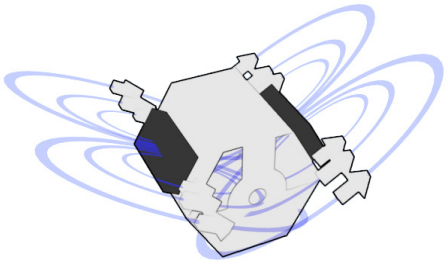




Now lower the magnets (being sure to keep the alignment) onto the motor. Tape or glue them to the sides.

Notice how the magnetic fields are not perfectly aligned, but are close to parralel. What is important here is that they are aligned in the same direction, approximately.





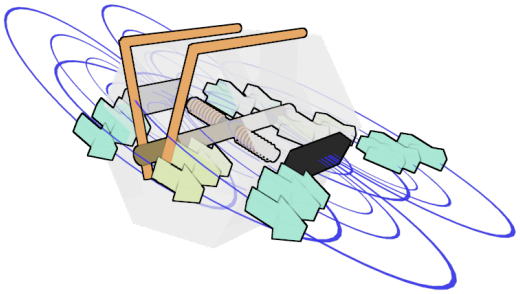
When we attach the electromagnet, it will become evident why we have them aligned this way.

Imagining the Motor

If we put the electromagnet into the motor now, what do you think will happen when we power it up? Write your description below. Remember to use complete sentences. Feel free to illustrate your work.

The Motor Explained

If we put the electromagnet into the motor as is, and power it up, it will rotate until it locks in place with the magnetic fields aligned along the axis of the outer magnets.



There is a vital piece of the motor that we need to add to make it work. Somehow we need to switch the direction of the electromagnet's magnetic field as it rotates. To do this we use the commutator.