



Student Content Brief – Advanced Level

Electric Motors

Background Information

Motors convert electric energy into mechanical energy. This mechanical energy turns the propellers on your Sea Perch. But what makes a motor spin? To understand how motors function it is important to understand how [magnetic fields](#) and [electric fields](#) are related.

Introduction to Electric Motors

Magnets are surrounded by magnetic fields and attract certain metals (iron, nickel, and cobalt). This magnetic effect comes from a special alignment of the atomic structure of the material. All magnets have two poles, a north pole and a south pole. It is impossible to have a singular magnetic pole; they always come in pairs. Magnets follow the rule that opposite poles attract and like poles repel.

Electric fields are created by charged particles such as protons and electrons. These charged particles can push and pull on each other with the [electrostatic force](#). The electrostatic force depends on the size of the charges and how close they are to each other. When you rub a plastic comb in your wool sweater and then hold it over tiny pieces of paper, they are attracted to the comb. They are pulled together, attracted to one another, by the electrostatic force. Charged particles follow the same rule as magnets. Opposite charges attract and like charges repel each other. When these charges move along a wire, an [electrical current](#) is produced. This current is what runs electrical appliances and electric motors.

Electromagnetics

Hans Christian Oersted discovered the relationship between mechanical force, magnetism, and electricity through a series of experiments in the early 1800's. He noticed that when a current flowed through a wire, it deflected a nearby compass. He understood that this meant the current flowing in the wire induced a magnetic field that turned the compass. Later it was discovered that when a wire conducting current is placed in a magnetic field, a force is induced on the conductor. This force is the basis for the electric motor.

The force is given by the equation:

$$F = iL \times B$$

where F is force, B is the magnetic field strength, L is the length of the conductor, and i is the current. Now that you have been introduced to the forces acting within a motor it is important to understand what is inside a motor.

Components of a Motor

The force on a conductor in a magnetic field can be turned into a [torque](#) by running current through a loop of wire in a magnetic field (as seen in Figure 2).

$$\tau = r \times F.$$

A torque, τ , is a force that causes an object to rotate. In this equation, F is the force applied and r is the distance from the pivot point where the force is applied. If r and F are perpendicular to each other, the torque is maximized. If they are parallel to each other, the torque is zero. You can apply this concept to what happens when you open a door. If you push on the door perpendicular to its surface, it will rotate around the hinges. If you push on the door parallel to its surface the door will not move.

When a motor is connected to an energy supply it creates a current that runs around the loop. This means the current is in one direction on one side of the loop and in the other direction on the other side. This creates a pair of force vectors (F in figure 2) in different directions. This causes a torque around the center axis of the loop (shown as a dotted line).

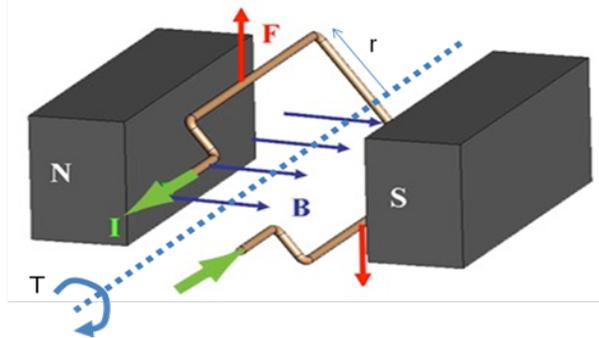


Figure 2: Schematic diagram of a coil of wire conduction current in a magnetic field.

Adapted from: http://hades.mech.northwestern.edu/wiki/index.php?title=Brushed_DC_Motor_Theory

Without any changes, the coil of wire will move, but it won't spin. It will stop once the torque has changed from the maximum value to zero. As shown in Figure 3, the forces on the coil will just cause the coil to align with the magnets and then it will stop.

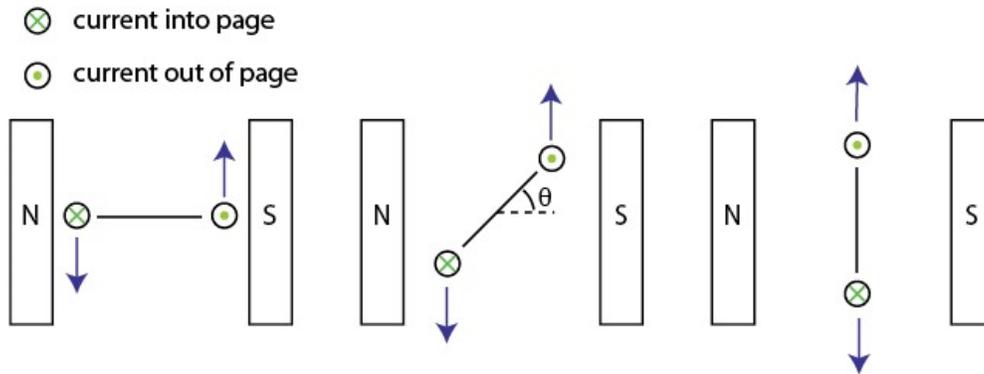


Figure 3: Schematic diagram showing the difficulty with a coil in a magnetic field.

Adapted from: http://hades.mech.northwestern.edu/wiki/index.php?title=Brushed_DC_Motor_Theory

There are a few different ways to make the coil spin, but the most common is to add physical components to make the current change direction, which will change the direction of the force (See Figure 4 for schematic of simplified motor components).

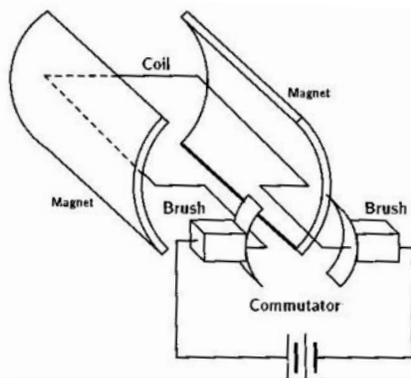


Figure 4: Internal parts of a motor. Adapted from: http://hades.mech.northwestern.edu/wiki/index.php?title=Brushed_DC_Motor_Theory

In order to switch the direction of the current, the electrical connection is switched using brushes and a commutator. A commutator is a rotary electrical

switch in an electric motor that periodically reverses the current direction between the rotor and the external circuit. The commutator is attached to the coil so it spins when the coil spins. The brushes are attached to the power source and do not move. As the commutator spins, the brushes automatically change the connection direction, thus switching the current direction.

How Electric Motors Relate to your Sea Perch

This is the type of motor that will move your Sea Perch through the water. The three motors will spin propellers so that you can navigate the Sea Perch. As you learn more about electric circuits you will experiment with ways to make the motor switch directions. You will also want to be able to change the speed of your motor.

Additional Resources

- If you would like to learn more about electric motors, please visit the following URL: http://en.wikipedia.org/wiki/Dc_motor
- For some additional information, try the following sites to engage in some interactive simulations <http://phet.colorado.edu/en/simulation/faradays-law> and <http://phet.colorado.edu/en/simulation/magnet-and-compass>