

The Direct Current Motor

12.6

When you start up your computer, the fan and the hard drive start to spin. You open the DVD or Blu-ray drive and watch the drawer open. You insert your movie, close the drawer, and wait for the disc to start spinning so the laser can read it and you can watch the movie (**Figure 1**). All of this would be impossible without the modern direct current (DC) motor.

Getting Motion to Occur Continuously

In the Mini Investigation in Section 12.5, you produced motion in a wire using a magnetic field. But the motion will only occur once. What if you want the motion to be continuous? Looking back at the galvanometer design, it is possible to get part of a complete turn, but the spring prevents further motion. Furthermore, the loop and the needle are forced back in the opposite direction once the coiled conductor has rotated past the halfway point. Scientists wanted to find a way to temporarily interrupt the current and then change its direction, and thus the direction of the magnetic field.

One simple but ingenious idea was to create a device called a split ring commutator. The commutator is split so that the circuit is incomplete when the loop is aligned with the split. In **Figure 2**, the wire loop is connected to a split ring commutator. The split ring commutator and the wire loop are free to rotate around an axis. The brushes are made out of conducting bristles. They make contact with the split ring commutator but still allow rotation. The rotor is the part of the motor that rotates and the stator is the part of the motor that remains stationary. In **Figure 2**, the loop is the rotor and the external magnets are the stator.



Figure 1 Watching a DVD on a laptop is possible because of a DC motor.

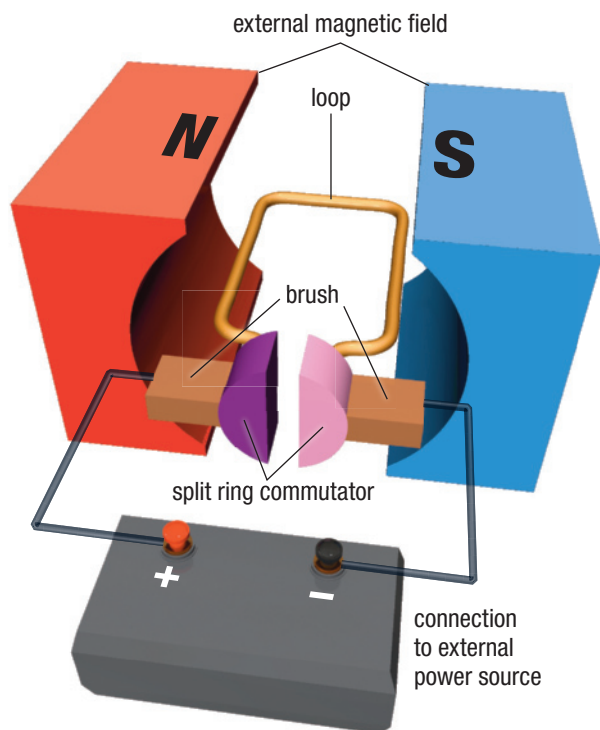


Figure 2 The parts of a DC motor

A DC motor uses an electric current in a conductor which generates a magnetic field that interacts with an external magnetic field to cause rotation. In the following Tutorial, we will go through the step-by-step process of how the DC motor spins and how the right-hand rule for the motor principle is applied.

Tutorial 1 The DC Motor

These four diagrams show the step-by-step process of how a DC motor turns.

In **Figure 3**, a conventional current is directed from the positive terminal toward the brushes, making contact with the purple part of the split ring commutator. Charges flow into the left of the loop and exit from the right into the pink part of the split ring commutator to the brush and back to the negative terminal. Using the right-hand rule for the motor principle, we see that the force is downward at the left of the loop and upward at the right of the loop. This will start a counterclockwise rotation.

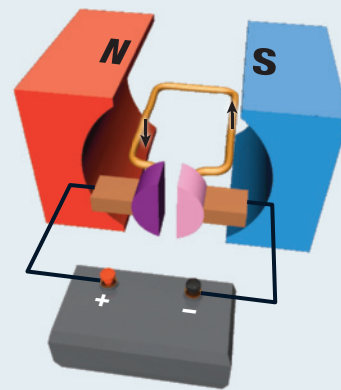


Figure 3

In **Figure 4**, the motor rotates counterclockwise, and the situation is the same as it was in the first step. The current is directed to the purple split ring of the commutator, and charges flow into the left of the loop and exit from the right of the loop. The forces are still in the same direction, as predicted by the right-hand rule.

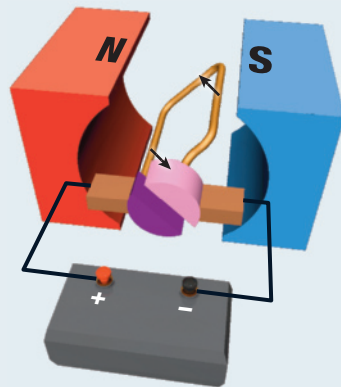


Figure 4

In **Figure 5**, the wire loop has rotated to the split. The circuit is now open, there is no current, and no more magnetic fields are being produced by the loop of wire. The loop will continue to spin due to inertia.

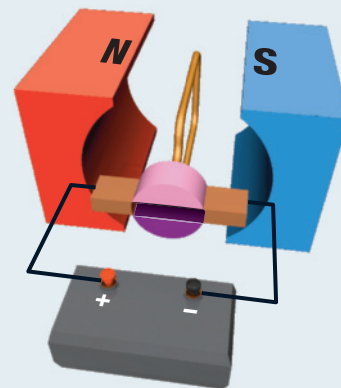


Figure 5

In **Figure 6**, the electric current is now directed into the pink part of the split ring commutator. This directs the current into the left of the loop once again and out of the purple part of the split ring to the brush and to the negative terminal. Using the right-hand rule, you can see that the right of the loop is being forced upward while the left of the loop is being forced downward. So the counterclockwise rotation continues.

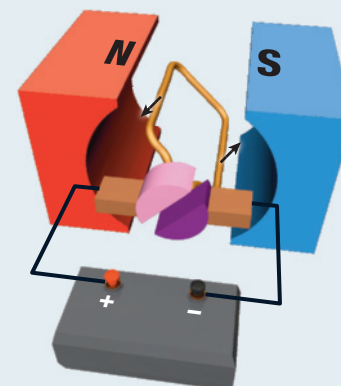


Figure 6

The rotation of the loop continues counterclockwise until it again reaches the split in the split ring commutator. This will once again interrupt the current until contact is made from the positive terminal to the purple part of the split ring commutator. The process will start over.

Improving the Design

The design of the DC motor shown in Tutorial 1 has some shortcomings. A motor with just one loop will not be very strong. To improve the strength of the magnetic field in the loop, you can increase the number of loops, increase the current, or include a soft-iron core. Increasing the current is not a desirable choice because it will produce more thermal energy as a side effect. So designers increase the number of loops and include a soft-iron core called an armature. In Tutorial 2, we will go through the step-by-step process of how a DC motor with an armature spins.

Investigation 12.6.1

Building and Investigating a Prototype Motor (p. 576)

In this investigation you will use what you have learned about DC motors to build a prototype motor and investigate its properties.

Tutorial 2 The Armature DC Motor

The next three figures show the step-by-step operation of a DC motor with an armature.

In **Figure 7**, the current is directed into split ring B. As a result, the charges go up the coil at the front of the coil and then exit from split ring A. Instead of using the right-hand rule for the motor principle, use the right-hand rule for a coil. Your fingers go up the coil following the conventional current and your right thumb points left, indicating that the left side of the coil is a north magnetic pole. The north pole from the external magnet and the north pole from the armature repel one another and cause a clockwise rotation. A similar thing happens with the two south magnetic poles.

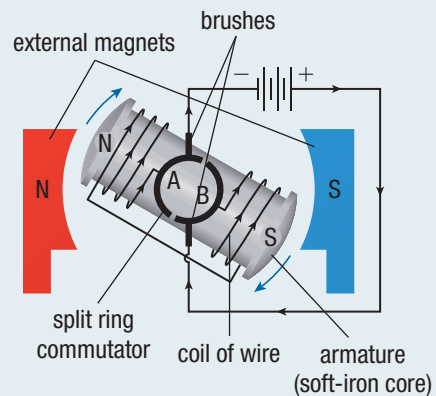


Figure 7

In **Figure 8**, the current is still directed into split ring B and the situation is the same. The clockwise rotation continues. Note that the north pole of the armature is attracted by the south pole of the external magnets. In the previous step, clockwise rotation occurred because of magnetic repulsion. Now clockwise rotation continues because of magnetic attraction.

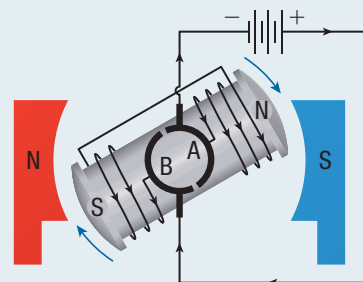


Figure 8

The armature rotates until it reaches the split. Now the circuit is interrupted and there is no current. The armature continues to spin due to its inertia.

In **Figure 9**, the current is now directed into split ring A. The charges go up the front of the coil and exit at split ring B. Using the right-hand rule for a coil, you can see that the left side of the armature is a north pole again. The north pole on the armature repels the north pole on the external magnets, and clockwise rotation continues. If the split did not occur, the left side of the armature would be a south magnetic pole and would be attracted back toward the external magnet north pole, stopping the rotation of the motor. Due to the split, the magnetic poles of the coil change and the coil continues to rotate.

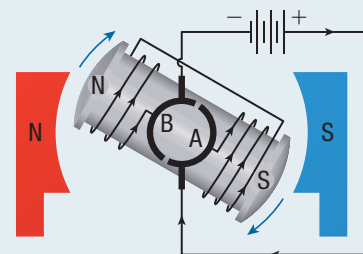


Figure 9

Mini Investigation

Observing a DC Motor

Skills: Performing, Observing

SKILLS
HANDBOOK  A2.1

Now that you have learned about the DC motor, you should be able to identify the parts of a DC hobby motor (**Figure 10**).



Figure 10

Equipment and Materials: DC hobby motor

1. Following your teacher's instructions, carefully disassemble a hobby motor.
2. Carefully examine each part of the motor and write a list of parts that you recognize and their function.
 - A. How many parts did you recognize? Are there any parts that you did not recognize? Record your answers in a t-chart. **K/U T/I C**
 - B. Did the design of the hobby motor look like the designs that you have studied so far? Explain. **K/U T/I C**
 - C. What parts were different in design from what you have studied so far? Give details about the differences. **K/U T/I**

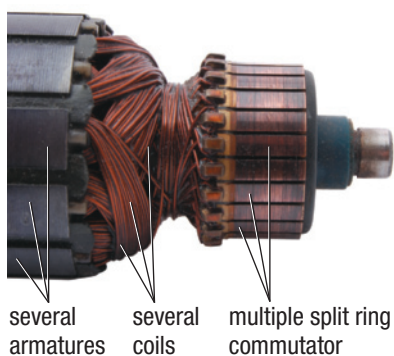


Figure 11 A DC motor with multiple split rings

Further Improvements in Motor Design

The armature design greatly improves the power of an electric motor. However, the magnetic force is strongest in the coil when it is lined up with the magnetic fields of the external magnets. As the coil rotates away from being lined up with the external magnetic field, the strength of the magnetic force on the coil weakens and the motor slows down. Another problem is that if the motor is turned off just as it reaches the split in the split ring commutator, then it will not be able to rotate when the motor is turned on again because the circuit is incomplete. You would have to give the motor a push.

To overcome these issues, DC motor designers put several coils into the motors and use a split ring commutator with several splits (**Figure 11**). This means that the speed of the motor does not fluctuate as much and a segment of the multiple split ring commutator is always in contact with the external circuit. The motor does not need to be pushed by hand to start it.

Applications of Motors

Electric motors are all around you and many mechanical movements you see are caused by an electric motor. They can be found, for example, in household appliances, cars, and trains. They are used to apply forces (for example, power tools), for cooling (for example, in laptop computer fans), as starters (for example, in cars), or to move things (for example, to spin a DVD).

Some cars now rely on electric motors for propulsion. Hybrid cars use an electric motor alongside a gasoline engine. The electric motor runs on battery power which reduces pollution from the gasoline engine. Once the battery runs low, the electric motor can no longer propel the vehicle. The car then runs on its gasoline engine and at the same time charges the battery. Some vehicle manufacturers have developed completely electric vehicles. While electric vehicles have the potential to be environmentally friendly, it does depend on how the electricity used to charge the battery is generated. Motors also contain heavy metals, which can be toxic to living things. Care must be taken to properly discard motors once they are no longer functioning.

Research This

Brushless Motors

Skills: Researching, Communicating

SKILLS
HANDBOOK  A5.1

The motor designs you have studied are still in use after many years because they are reliable and economical. However, the brushes in these designs make contact with the split rings and can wear out. Also, brush designs often produce small sparks as the brushes go past the splits. There is a design that does not use brushes.

1. Research brushless motor designs and their applications.
 - A. Create a t-chart comparing the designs of brushless motors to brush-type motors. T/I C
 - B. Explain how brushless motors work, and identify the stator and rotor. T/I C
 - C. What advantages do microprocessor-controlled brushless motors have? T/I C A
 - D. List some applications of brushless motors. C A



GO TO NELSON SCIENCE

12.6 Summary

- The split ring commutator is the part of a DC motor that interrupts the circuit. It changes the direction of the current and the direction of the magnetic field, keeping the motor spinning continuously.
- A DC electric motor consists of a rotor and a stator.
- A DC electric motor uses an electric current to produce a magnetic field in a coil. The coil starts to rotate in an external magnetic field.
- Brushes make physical contact with the split ring commutator to complete the circuit and still allow rotation.
- Using a soft-iron armature and increasing the number of loops in the coil will increase the strength of the motor.
- Using several split rings and coils prevents the need to manually start a motor.
- Motors are used in many electrical devices.

UNIT TASK BOOKMARK

You can use what you have learned about the design of DC motors as you work on the Unit Task on page 622.

12.6 Questions

1. (a) Identify the parts labelled A, B, C, D, E, and F for the motor shown in **Figure 12**.
- (b) Determine which way the motor will spin. Explain your answer.
- (c) What effect will reversing the current have? K/U T/I C

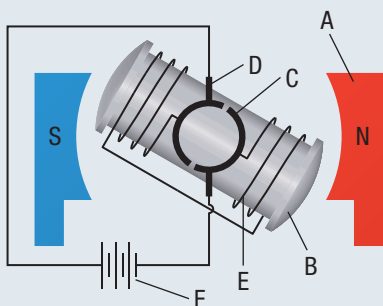


Figure 12

2. (a) Look at **Figure 13**. In which direction will the loop rotate? Explain your answer.
- (b) What is the purpose of the split ring commutator?

K/U T/I C

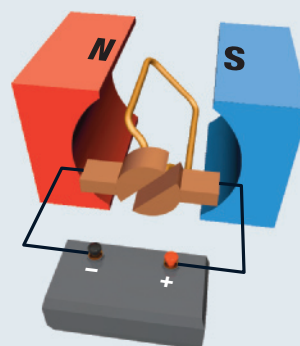


Figure 13

3. What effect would each of the following changes have on a DC motor? Consider each of the changes separately. K/U
 - (a) increasing the number of loops in the coil
 - (b) using a plastic core instead of a soft-iron core
 - (c) decreasing the current
 - (d) reversing the polarity of the external magnets
 - (e) reversing the polarity of the external magnets and reversing the direction of the current