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Catalog No. AP6263
Publication No. 6263

DC Motor Made Simple

Student Laboratory Kit

Introduction

Motors are the fundamental driving force of the modern world. It is a very rare occasion when the action of a motor is not used in daily living. So how do they work? With this activity, build your own simple DC motor and find out.

Concepts

- Energy transfer
- Electrical current
- Magnetic fields

Background

An electric motor converts electrical energy into mechanical energy. A generator, on the other hand, converts mechanical energy into electrical energy.

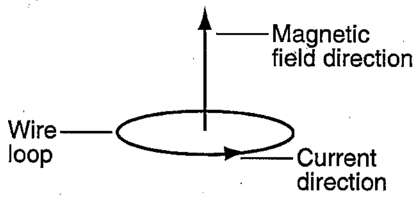

Figure 1.

For this simple DC motor, electric charge flows (electric current) through the coil armature from a direct current power source. *Direct current* (DC) is current that travels in only one direction, as opposed to *alternating current* (AC) which switches rapidly. A property of a moving electric charge is that it produces a magnetic field. Therefore, a magnetic field forms around the wires in the coil armature when current flows through it. The direction of the magnetic field is perpendicular to the loop face through the middle of the loop. (Use the "right-hand rule" to determine the direction of the magnetic field produced by a current-carrying loop—curl your fingers on your right hand in the direction of the current flow in the loop. Your thumb will point in the direction of the "north end" of the magnetic field.) A constant external magnetic field (a magnet) is then applied. The repulsion and attraction of the magnetic fields produced by the current through the coil armature and the external magnet generate a rotational force on the coil armature that causes it to spin—electrical energy from the battery is converted into mechanical energy.

The rotational force arises because the fields tend to align themselves so that they point in the same direction. The "direction" of a magnetic field is defined to point from the south pole to the north pole in a bar magnet. The tendency for magnetic fields to align explains why the north poles (or south poles) of two bar magnets repel each other. When the north poles of two bar magnets point at each other, their magnetic fields point in opposite directions. If one magnet is secured to a table and the other is free to spin, the rotational force produced between the two magnets would cause the freely-spinning magnet to turn 180° so that its north pole points in the same direction as the north pole of the secured magnet. The same phenomenon occurs with the spinning, current-carrying coil armature and the external bar magnet. When the magnetic fields are out of alignment, an induced rotational force tends to bring the magnetic fields into alignment and causes the coil armature to spin in the process.

In order for the motor to work, however, the coil armature must continue to spin. For this to occur, the magnetic fields must either change direction, or disappear once the magnetic fields are aligned. Once the magnetic fields are aligned they will tend to stay in line and the spinning will stop. For this simple DC motor, the magnetic field in the coil armature disappears every 180° (approximately) because the current flows through the coil armature only when the exposed copper on the axles of the armature come in contact with the copper posts connected to the electrical power source. When the insulating enamel coating is in contact with the copper posts, the electrical circuit is open and no current flows. When there is no current, there is no magnetic field in the coil armature.

The largest rotational force occurs when the magnetic fields produced by the current in the coil armature and the external magnet are at right angles to each other. The direction of the induced spin is determined by the direction the current is traveling in the coil and the external magnetic field direction. The coil will spin in the direction that will align the magnetic fields. (The motor will spin in a definite direction that can be switched by changing the direction of the current or by changing the polarity of the magnet.) The rotational force will spin the armature until the current is broken as insulated enamel contacts the copper posts. The coil continues to spin due to its momentum until the current flows 180° later and the magnetic field is produced again. The rotational force rotates the armature in the same direction as before to align the magnetic fields so the force adds to the momentum the coil already has and the coil spins faster.

Materials

- Battery, 9-V
- Battery clips with alligator clip leads, 9-V, or connector cords with alligator clips, 2
- Copper wire pieces, 16 gauge, 8 cm, 2
- Foam block, 7.5 cm × 7.5 cm × 2.5 cm
- Magnets, ceramic disc, 2
- Magnet wire, 20–22 gauge, 60 cm
- Pliers, needle-nose with wire cutters
- Sandpaper strip
- Tube or rod, approximately 2 cm in diameter

Safety Precautions

This activity is considered nonhazardous. Although 9V batteries do not have enough electrical current to be harmful, please exercise caution and follow all normal laboratory safety guidelines.

Procedure

1. Obtain 60 cm of magnet wire and a tube or rod approximately 2 cm in diameter (such as a pen, PVC pipe, battery, etc.).
2. Tightly wind the magnet wire around the tube or rod to create a thinly-coiled loop. Wind completely (approximately 15–20 coils) and leave 2–3 cm of free wire at both ends. The two free ends of the wire should be 180° apart when the winding is complete.

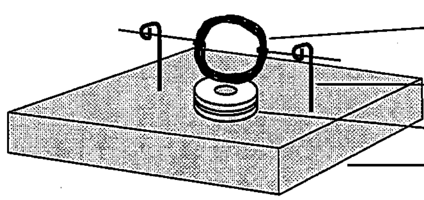

Figure 2.

3. Carefully pull the coil off the tube or rod.
4. To secure the loop shape permanently, wrap each free end through the loop and around the coil of wire 2 to 3 times. Make sure the binding loops are 180° apart and wrapped tightly around the coil wires. Straighten the free ends so that they are perpendicular to, but in the same plane, as the coil to serve as the axle for the coil armature (see Figure 3).

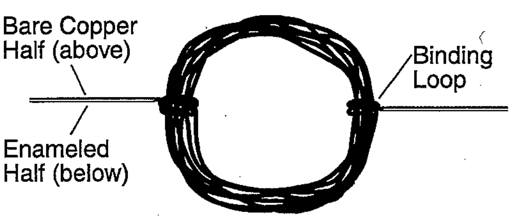

Figure 3. Coil Armature

5. Check the balance of the coil armature by spinning the coil by the axles between your thumbs and index fingers. Make sure the coil spins smoothly.
6. Obtain a small piece of sandpaper. Hold the coil at the edge of a table so the coil is straight up and down and one of the free ends is lying flat on the table. With the sandpaper, sand off the top half of the insulating enamel. Leave the bottom half of the enamel intact. Do the same to the other free end. Make sure the shiny bare copper side faces up on both ends (see Figure 3).
7. Obtain two 8-cm long pieces of 16 gauge copper wire (uninsulated).
8. Use needle-nose pliers to make a small, complete loop at one end of each piece of copper wire. If necessary, use the needle-nose pliers to straighten the copper wires as well (see Figure 2).
9. Obtain an 8 cm × 8 cm foam block.
10. Insert the copper wire posts into the foam block so that the loops are approximately 5 cm apart and about 3 cm above the foam surface.
11. Place the coil armature axles into the loops in the copper wire posts. The axle of the coil armature should be parallel to the foam surface and the armature should be balanced and able to spin freely (see Figure 2).

12. Place the ceramic magnets on the foam block directly beneath the coil armature.
13. Connect one alligator connector cord to the base of each copper wire post. Connect the other ends to a 9-V battery.
14. To start the DC motor, give the coil armature a slight spin. If it does not begin to spin continuously, give the motor a spin in the opposite direction. If it still does not spin continuously see *Tips* section.

Tips

If the motor does not spin continuously:

- Be sure the straight wires from the coil armature are 180° apart and positioned from the center of the magnetic wire coil.
- Check to make sure the enamel on the axle is completely removed and the copper wire is exposed on only one side so that half the "axle rod" is copper and the other half is enameled. Make sure that the copper side and the enameled side are the same for both axle ends. Make sure the coil spins freely on the copper coil loops and that it is balanced and level to the ground.
- Check to make sure the electrical circuit is closed and the battery has enough power. Connecting the leads closer to the loops in the copper coil posts may help. Also, remove any tarnish or contamination that may be on the copper wire post loops with sandpaper.
- Manually adjust the position of the magnet by holding the magnet above the coil armature with the north or the south end of the magnet pointing at the coil armature. Adjust the distance and position of the magnet while initiating the spin to the coil armature. Determine the best distance for the magnet. The height of the copper posts above the foam can be adjusted accordingly.
- Once the motor spins, adjust the position and the polarity of the external magnet and observe how the motor spins.

Disposal

Consult your instructor for appropriate disposal procedures.

Name: ____________________ Date: ____________ Hour: ________

DC Motor Kit Post-Lab Questions

1. List the different types of energy present in this experiment.

2. Why is the motor that you made in this lab considered a DC motor?

3. In your own words, describe why the magnetic field of the ceramic magnets causes the metal coil to rotate when it is connected to the battery.

4. Predict what would happen to the rotation of the magnetic coil if the wires or clips were switched from one copper post to the other (that is, transposed).

5. Write 3 testable questions which can be answered by modifying your current setup. Select one question that you want to investigate, have me initial it, once approved you and your partner(s) can perform the experiment and find your answer to the question.