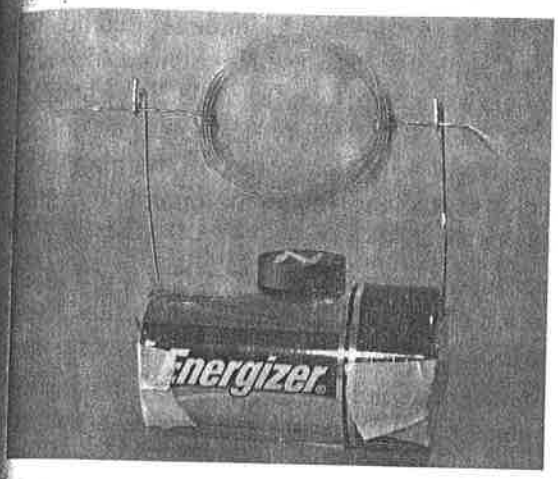
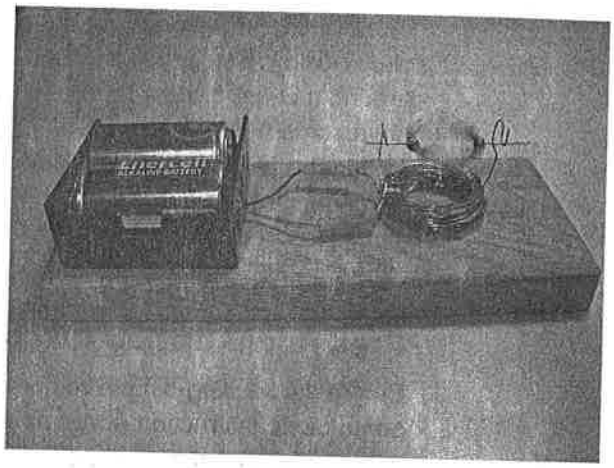
Instructional Information





Overview

Using some very simple materials, you can produce an electric motor with which you can demonstrate the principles of magnetism. A variation of the simple motor replaces the usual ceramic magnet with a coil of wire to form an electromagnet. Both pieces are fairly simple to build and can be entertaining as well as instructional.

Student Skills

Design and Construct. Students can build their own motor specifically following the directions given in this book, or they can attempt to improve on this design. This motor is an introduction to how motors work. There are many designs for motors that are more efficient and useful.

Observation. Students can observe the action of the motor turning and manually feel the forces exerted on the coil by holding it in place while it is energized.

Application. Students can expand on the concept of magnetism by identifying other situations in which electromagnets can be used.

Related Concepts or Processes

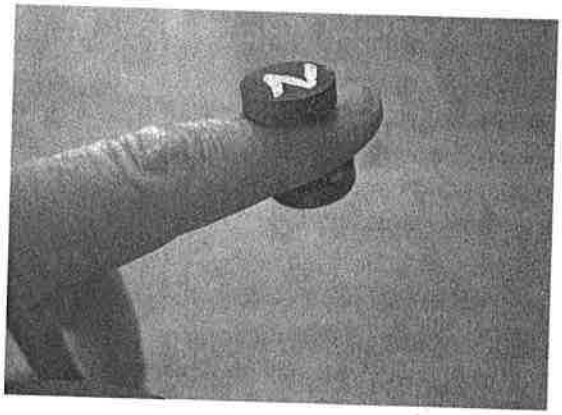
Electricity
Circuits
Torque
Magnetism
Series circuits
Currents

Prior Knowledge

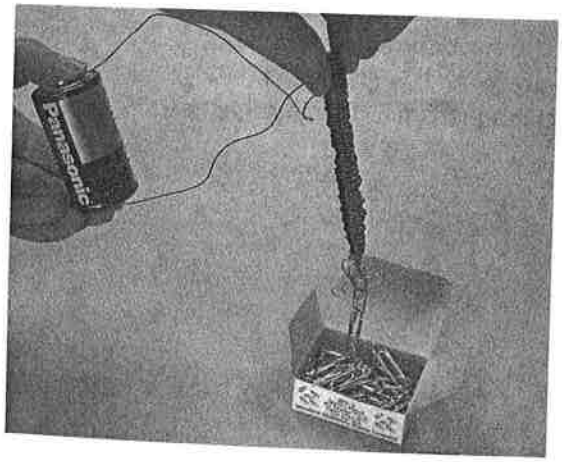
The simple motor is an engaging activity for students in grades four and higher. Younger students can construct these motors with adult supervision and assistance. For this activity to be appropriate, students should have some basic understanding of electricity and magnetism. They should know that electricity needs a complete circuit to flow. Before building the motor, students also should know that wrapping wire around a D-cell battery to form a coil would increase a magnetic field. They should have some understanding that magnetic fields can attract or repel other magnetic fields. The attraction or repulsion is dependent on the orientation of the magnets. Students viewing the double-coiled motor should understand the operation of the simple motor prior to viewing this additional piece.

Predemonstration Discussion

Before introducing simple motors, you should dedicate some time to a review or some basic instruction about magnet fields and electricity. Here are two activities that every student should experience.



Every student should have the opportunity to discover the attraction and repulsion of permanent magnets. Simple disk magnets are extremely cheap and available from a variety of sources. Try to find magnets that are identified with an *N* and an *S* to identify the field polarities. If they are not, use paint or permanent marker to mark them. Paper correction fluid also works quite well.



Sometime in every student's education, he or she should experiment with an electromagnet. A large nail wrapped with wire, a battery, and a box of paperclips allows students to explore magnetism and its properties.

Questions for review can include the following:

- How can you form an electric magnet using wire and a battery?
- How does a magnet affect other magnets?

- What kinds of materials are attracted to magnets?
- How does a compass work?
- How are permanent magnets and electric magnets similar? How are they different?
- How does the magnetic field produced by an electric magnet compare to a magnetic field produced by a permanent magnet? Will one type affect the other type?
- In what direction does the magnetic field extend out from a coil of wire?

Suggestions for Presentation

There are a variety of plans for the production of simple motors. The plan for this motor has been successful with students of all ages because of the minimal material requirements and the ease of building it. Students can work alone or in pairs to assemble this piece. The method of explaining the assembly procedure can also vary according to the needs and abilities of the students.

A few methods you might use include the following:

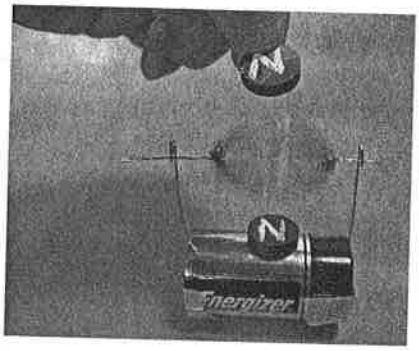
- Copy the assembly instructions in this paper and give them out as handouts for students to follow.
- Make a large poster that shows each step of the assembly process.
- Guide students though the assembly process step-by-step as a demonstration. Perform each step and have students repeat the procedure for themselves. As students proceed, keep an eye on their progress. When everyone has completed one step, go on to the next one.
- Set a completed model on a demonstration table and show students how it works. Set out an assortment of materials and have students build their own version. They can examine the model and make changes to try to increase its efficiency.

Due to the imbalance of the coil and the repulsive nature of magnetism, the coils tend to jump off the support bars rather frequently. After students have completed the initial assembly, you could hold a short contest to see whose motor can stay running for the longest time. Have students do some brainstorming to design ways to keep the coil seated on the support posts.

Interactive questions for discussion after the motors have been successfully assembled include the following:

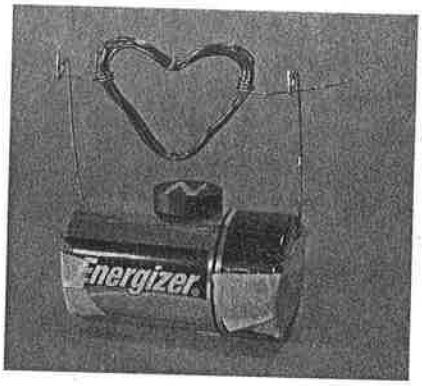
- When you hold the coil in the energized position on the supports, what type of force is exerted between the coil and the permanent magnet?
- Is the coil attracted or repelled to the permanent magnet?
- Is there a position in which the coil is attracted to the permanent magnet?
- What happens to the magnet field when the enameled part of the wire is touching the support?

- As the coil spins on the supports, describe what happens when the coil gets a push from the magnet?
- What would happen to the motion of the coil if it did not get a push each time it turned on the supports?
- How can we get the coil to spin in the opposite direction? (There are two ways.)



Another part of this demonstration shows a method for improving the efficiency of this motor. This requires a second magnet to increase the magnet field near the coil. Have students hold the second magnet about ½ inch above the spinning coil. When the coil is energized, it will push against both magnets. If the magnet is held close enough, a student can feel the force applied between the magnet and magnetized coil.

If you flip the handheld magnet over, it will attract the coil instead of repelling it. When you bring the magnet near the coil, it will slow down or even stop the coil movement.



Students can also experiment with altering the shape of the motor coil. I call the coil the St. Valentine's Day Special. Other shapes could be ovals, squares, triangles, and figure eights. Students will have to rebalance the coil, but most shapes will still work.

The double-coiled motor

After you have demonstrated and explained the simple motor, have a short discussion about the similarities between the fields exerted by electric magnets and the permanent magnets. If someone questions whether the permanent magnet can be replaced with another coil, it is a good lead-in for students to explore this possibility. Most successful student-designed models will use a separate battery for each coil.

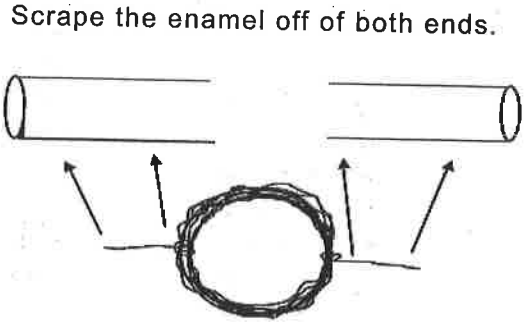
Don't introduce the double-coiled motor shown in this section until students have had the opportunity to try building their own version. In most cases, students will opt for keeping the bottom coil energized all the time. The double-coiled motor is built with the two coils acting in series. You may need to review series circuits before or during this demonstration to students.

Interactive questions and discussion of the double-coiled motor could include the following:

- How are the simple motor and the double-coiled motor similar?
- How are the simple motor and the double-coiled motor different?
- Trace the flow of electricity from beginning to end for the double-coiled motor.
- What might be some advantages or disadvantages of this type of motor?
- Which setup for the motor will require more electricity to operate?

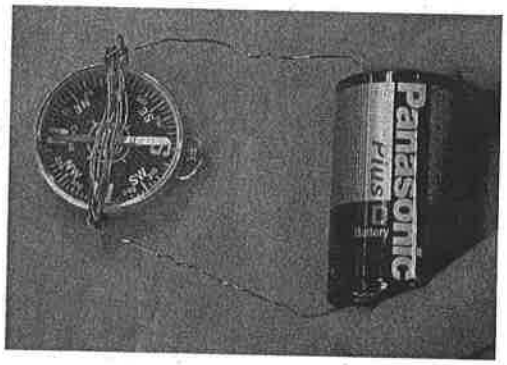
Postdemonstration Activities and Discussion

The directions in this article call for scraping all the enamel off one wire and half the enamel from the wire on the other side. Students will find it amazing to discover that coil will still turn if both sides are scraped clean. They can try this with their original coil or make a second one and scrape both protruding wires completely clean. This setup works because the coil bounces upward during the magnetic "push" and breaks the electric circuit.



Hans Oersted's (1777–1851) famous discovery showed electricity could form magnetic fields and that the direction of the lines of force radiates perpendicular from the wire. Students can build a tangent galvanometer to show the magnetic field produced by coil and battery.

This coil of wire is wrapped around a compass and then energized by a battery. The compass needle will spin a few turns and then settle down to sit perpendicular to the coil. It demonstrates that the magnetic fields can run through the coil and form directly perpendicular from the wire instead of parallel to it as was earlier thought. The field increases with the number of turns in the coil.

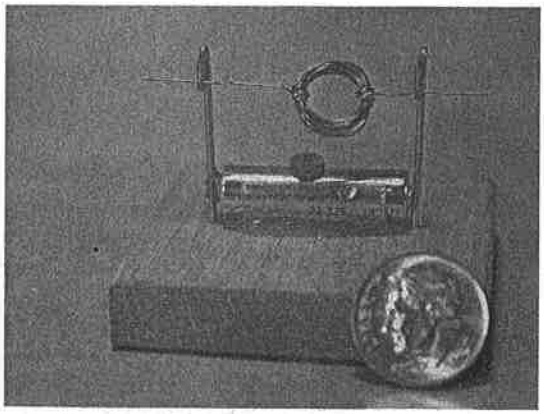


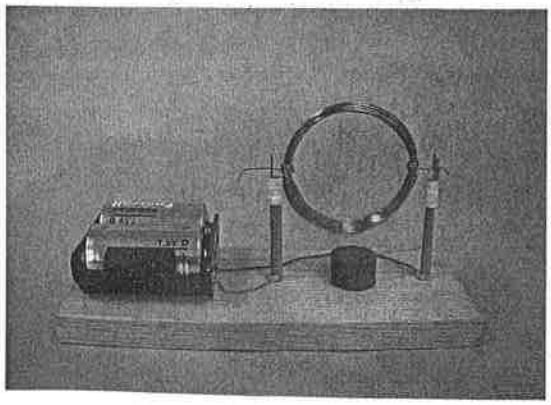
Discussion of Results

The simple motor works because electricity travels through the coil of wire and temporarily forms a magnetic field. This magnetic field forms only when the bare wire touches the metal supports. The field shuts off when the enameled side of the coil wire is touching the supports because the flow of electricity is interrupted. The flow resumes again as the coil turns back into the position where a magnetic field is produced. You can feel the magnetic repulsion by holding the coil in place with the shiny ends down against the metal supports.

When the coil becomes energized, it will push away from the ceramic magnet with enough force to turn through one revolution. The turning coil has enough rotational inertia to keep it turning though the position of no magnetic field. As the coil continues to turn, it returns to the position where it becomes charged again. The coil gets another push as it passes through the magnetic field once more. This process repeats itself over and over as the motor continues to spin. The action can be very rapid and may be occurring up to 10 times per second.

The double-coiled motor operates on the same principle as the simple motor. The obvious difference is that the ceramic magnet has been replaced with an electric magnet made with a coil of wire. What is not obvious is that both coils are hooked up in a series with electricity flowing through one coil and then the other. The motor coil acts as an on-off switch as it does for the simple motor. Now when the bare wires of motor coil makes contact with the supports, electricity flows, and both coils become electric magnets. The magnet fields repel each other, causing the motor to turn. When the motor coil turns far enough and breaks the circuit, both coils shut off. The motor coil has enough rotational inertia to continue turning and both coils become energized again. The process repeats itself over and over to keep the motor spinning.





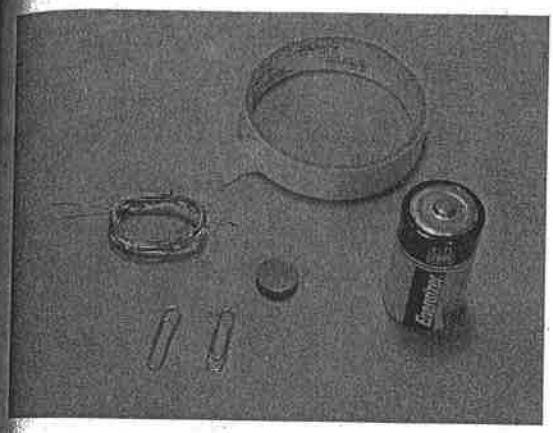
Additional Activities

Here are a few more possible additions to the simple motor design.

How small can these types of motors be made? You can see the small size by looking at the dime in front of this little motor. It was made with a small battery sold for hearing aid use. The coil was made by wrapping the wire around a pencil. It spins just as well as a larger one.

How large can they get? The larger size allows for easier viewing when you are discussing the principles of its operation, so this size works well as a teacher demonstration piece. The coil was made by wrapping 18 feet of copper bell wire around a soda can. The magnet was glued to the base. The supports can be long bolts or nails. Electrical wire fittings were added to the top of the bolts for the coil to reside in.

Directions for Assembly



Student Motors

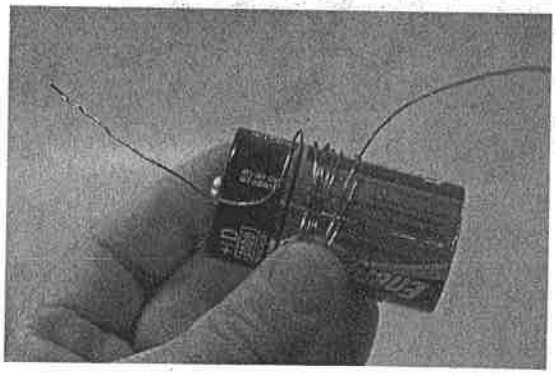
Materials

- 1 D-cell battery
- 1 small magnet
- 1 piece of enameled copper wire, 20 gauge, 50 in. long
- 2 paper clips
- masking or plastic tape

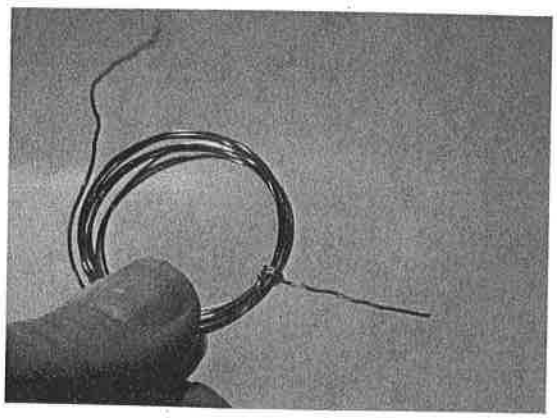
Directions

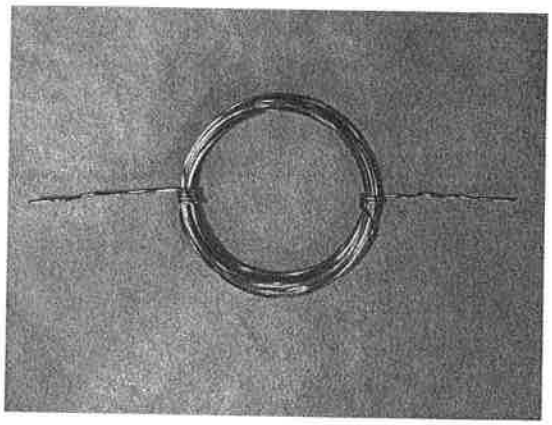
1. The armature is the first step in the production of this simple motor.

   Start by straightening out any kinks in the enameled copper wire. Next, bend a 2-inch portion of the wire to form a 90-degree turn. Using your thumb to hold the bent portion of the wire against the side of the battery, wrap the rest of the wire around the battery to form a coil.

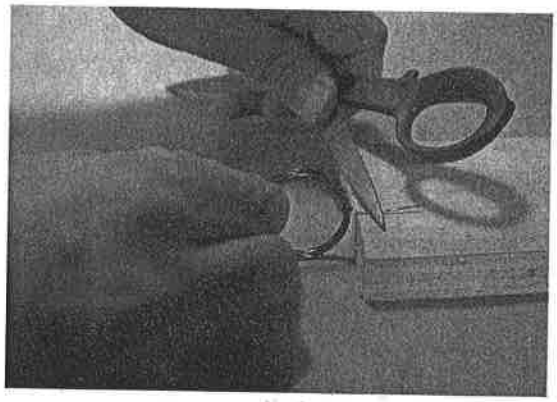


2. Remove the coil from the battery while holding it together between thumb and forefinger. Wrap the extended wire 2 to 3 times around the coil to hold it together. The coiled-up wire should have a short piece protruding on opposite sides of the coil. Wrap this second wire around the coil also.





3. With the wire wrapped around both sides of the coil, check to see that they are directly opposite each other. If the ends protrude more than 1 inch from the coil, it can be trimmed or wrapped as extra turns around the coil. Straighten out the 2 protruding wires as much as possible. Extra bumps may hinder the movement.



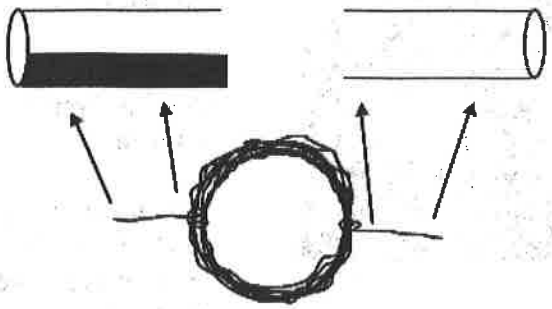
4. Lay one of the ends of the wire flat against a hard surface such as a piece of plywood. Use the sharp edge of the scissors to scrape the enamel off the protruding wires. Turn the coil as you are scraping and remove all the enamel completely off the entire length of this side. Note the wire on the other side of the coil will differ significantly in the directions given in step 5.

5. The preferred method of production is to remove the enamel from just the top half of the second side of the coil. Hold the coil vertically with one hand and lay the other side of the wire against the hard surface. It is important that you scrape only the top half of this piece of wire. The bottom portion of the protruding wire should remain coated with the enamel. (See the drawing on the next page.)

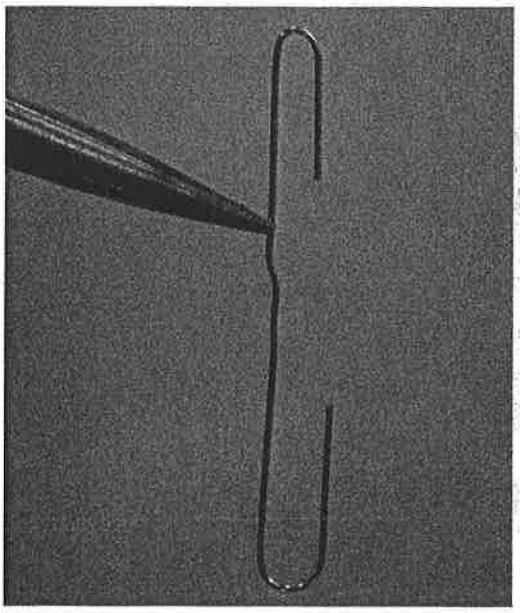
   Look at the additional activities section for information on making another coil with both protruding wires stripped clean of enamel. In this instance, the enamel is scraped off of this wire all the way around.

The top half of this wire is scraped clean; the bottom half of the wire still has the enamel left on it.

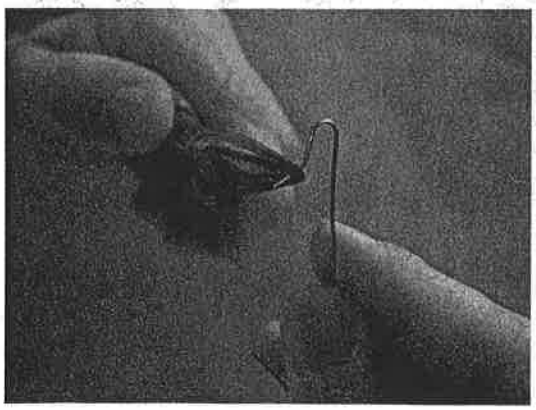
The enamel is scraped off of this wire all the way around

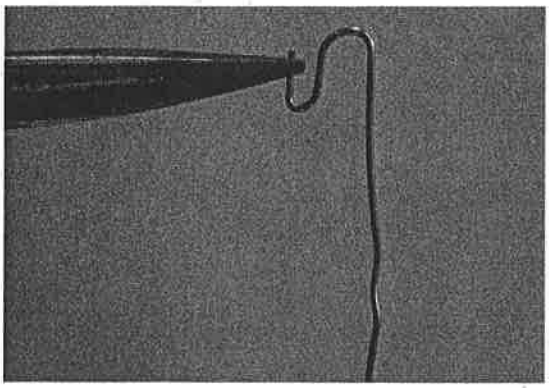


6. The coil is going to be supported on 2 bent paper clips. To make these holders, start by unbending the center portion of both paper clips. Try to straighten out the center of the clip as much as possible.



7. Use a set of needle-nosed pliers to firmly grasp the bottom half of the small end of the paper clip.

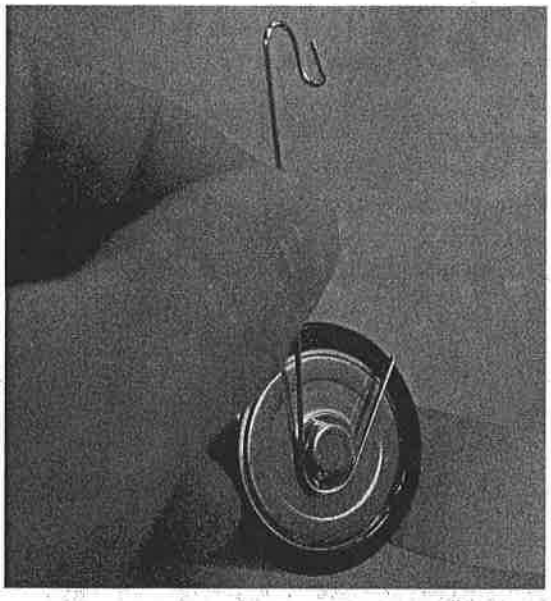




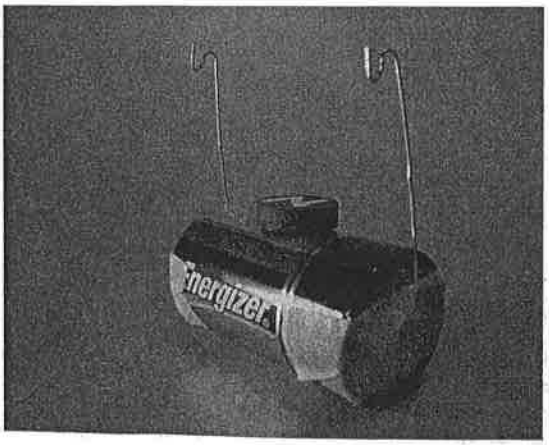
8. Use the pliers to bend a small portion of the paper clip upward to form a small U-shaped channel for the armature to sit in. Repeat this activity for the second paper clip.

   The larger bent U sections of the paper clips are bent outward to form more of a V shape.

   After the motor is working, the U section can be bent into an O shape. This will help to keep the motor from jumping off the supports.



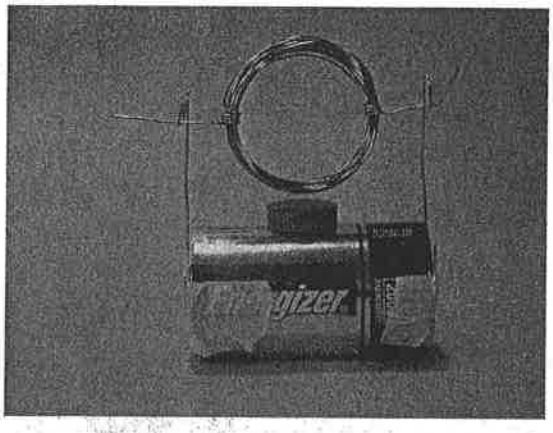
9. Use a few pieces of masking or plastic tape to hold the whole motor together. Tear off a 2-inch portion of tape and use this to attach the first paper clip to the side of the battery. The little knob on the battery should fit into the V portion of the paper clip. Position the second paper clip on the opposite side of the battery using another piece of tape.

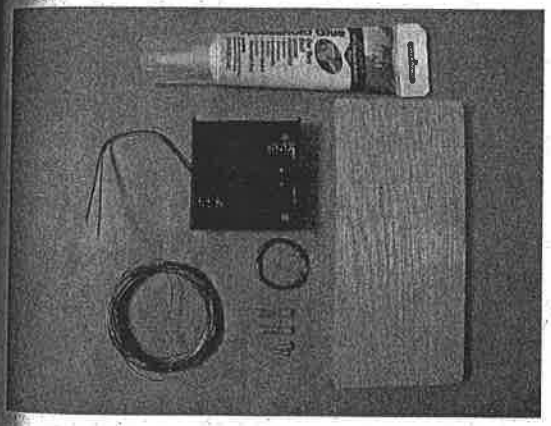


10. Both paper clip supports should have the bend at the same height, or the armature will fall off the support as it is spinning. The magnet is placed directly on top of the battery; it should be centered between the 2 paper clips. A piece of tape can be used between the battery and the table surface to keep the battery from rolling over during its operation.

11. Set the coil into the small folds of the paper clips, and make sure that it is balanced. If the coil does not turn evenly, bend the protruding wires to make it balanced. Give the coil a gentle push to get it to start spinning. If it does not spin, try spinning it in the opposite direction. Also, squeeze the paper clip posts tight against the sides of the battery to make sure they are making a good connection.

You can bend the ends of the protruding wire to help keep the coil centered over the magnet.





Two-Coil Motors

Materials

- battery holder, 2 D-cell
- wood block, 4 x 8 in.
- coil copper wire, 25 ft. of 20-gauge enameled wire
- coil copper wire, 4 ft. of 22 gauge enameled wire
- wire connectors
- screws, ½ in. long
- glue

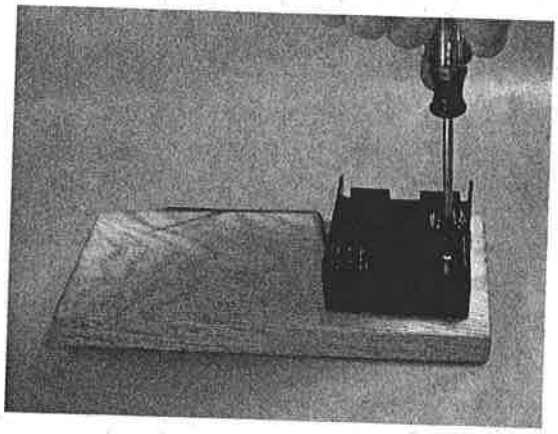
SAFETY NOTE

When you are completing the wood base, using the following safety equipment is strongly suggested:

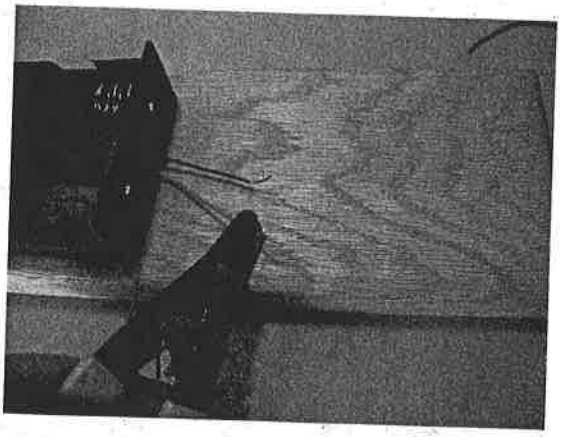
- Goggles for eye protection. NSTA recommends that you use safety goggles that conform to the ANSI Z87.1 standard and that provide both impact and chemical-splash protection for all science laboratory work.
- Dust mask to guard against breathing in airborne sawdust.
- Gloves whenever power tools are used.

Directions

1. Cut the wood block to an approximate size of 4 by 8 inches. Sand all the edges smooth and paint with 1 or 2 coats of varnish.



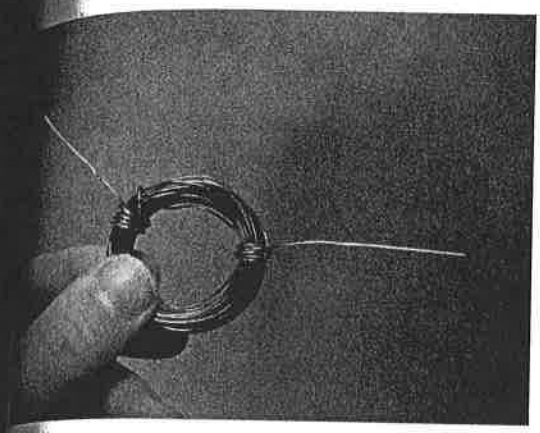
2. After the varnish dries, the battery holder can be mounted to the wood block base. Inside the battery holder are holes for mounting screws. Drill pilot holes and attach the battery holder to the base by screwing in the screws.



3. The wire extending out of the battery holder should be only about 2 inches long. Cut off excess wire from the battery holder. The wires should have about ½ inch of plastic insulation removed. Use wire strippers or scissors to remove the plastic coating from the end of the wire.

4. The large coil that replaces the permanent magnet is made out of 25 feet of enameled copper wire. Wrap the wire 50 times around a D-cell battery to form the coil. After wrapping the wire around the battery, remove the coil and hold onto it, or the wire will unwind. Press the turns together to pack the wires as tightly as possible.

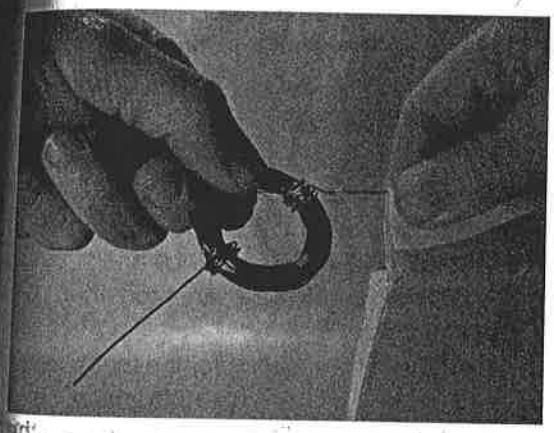
   Fewer turns might not produce a strong enough magnetic field to spin the coil.



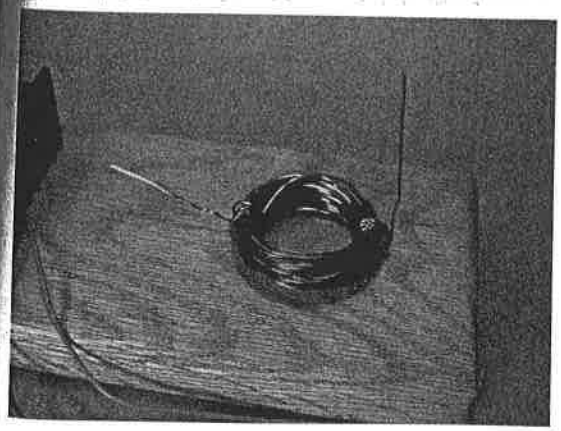
5. Take one of the ends of the wire and wrap it 3 or 4 turns around the coil of wire to hold it together. Tuck the end of the wire under one of the turns and then loop it around to knot it in place.

   The second end of the wire should be wrapped around the opposite side of the coil. It should be placed slightly above the center of the coil instead of directly across from the first side. This space will be used by another wire that is added in step 8.

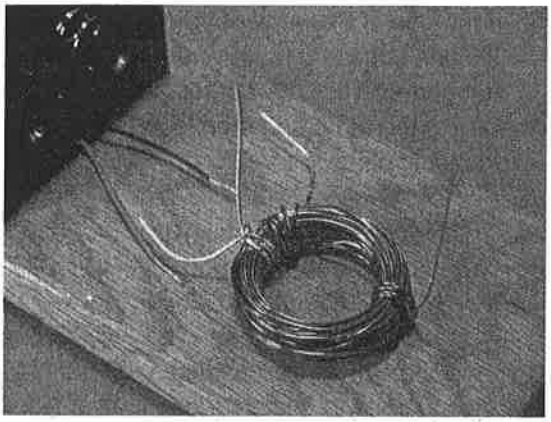
   Cut both wire ends down to about 3 inches in length.

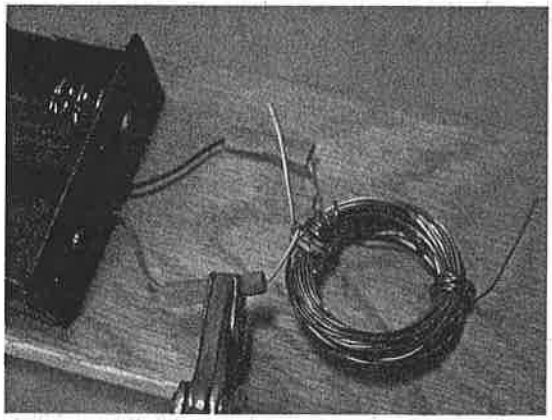


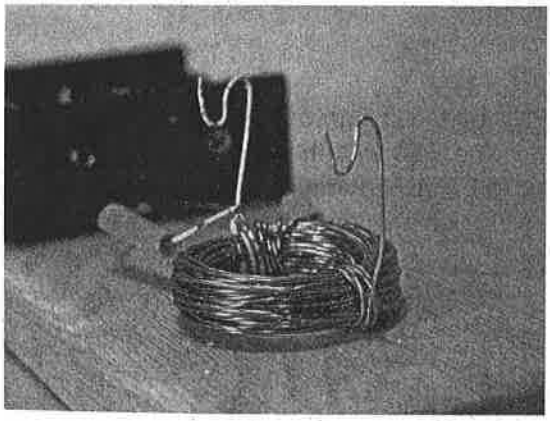
6. Use sandpaper to remove the enamel from the end of the wire that was just wrapped around the coil. Only about 1 inch of wire needs to be sanded clean.



7. Lay the coil down against the wood base. The wire with the end scraped clean will be attached to one of the wires extending out from the battery holder. The other wire from the coil should extend straight up from the base. This wire will form the right side motor coil support.





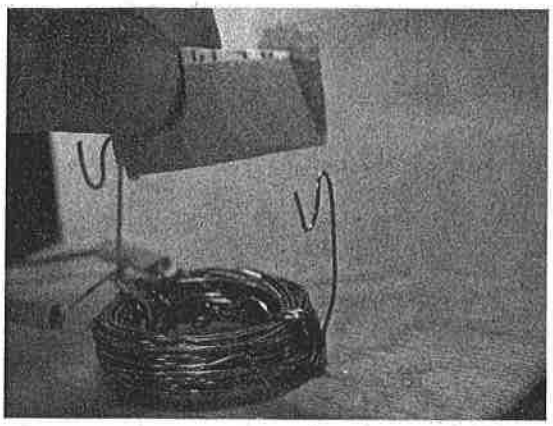


8. Cut an 8-inch piece of wire from the leftover supply. This wire has been painted white to make it easier to identify it in the pictures. The separate white wire is wrapped around the coil directly opposite from the right side support. Three inches of white wire extend up from the coil. This will form the left side support. The white wire is wrapped around the coil 3 or 4 turns and then tucked under one of the previous turns; this will knot it and hold it in place.

9. The next step is to attach the battery holder using wire connectors. The black wire is shown connected to the scraped wire that extends out from the coil. Stick each end of the wires to be joined into the opposite ends of the connector. You must squeeze the connector hard with pliers; this will lock the wires together. Sand the end of the white wire to remove the white paint and the enamel. Then join this wire to the red wire from the battery holder. Once again, use a connector to join the 2 wires together.

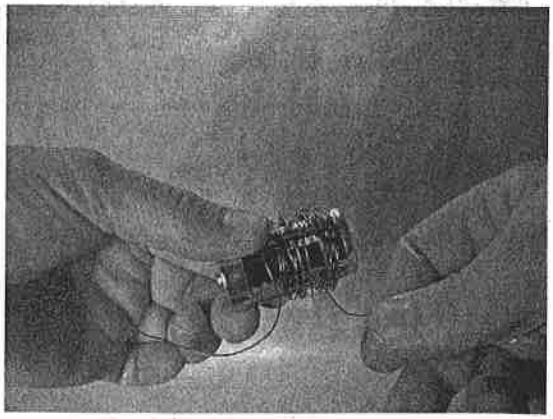
10. Bend the wire supports for the motor into a sideways S shape. To get this shape, bend the top inch of both wires down toward the base. The next step is to bend the last ½ inch of these wires back up again as shown in the picture. Both of the U-shaped slots should be at the same level or the motor will slide toward the lower side.

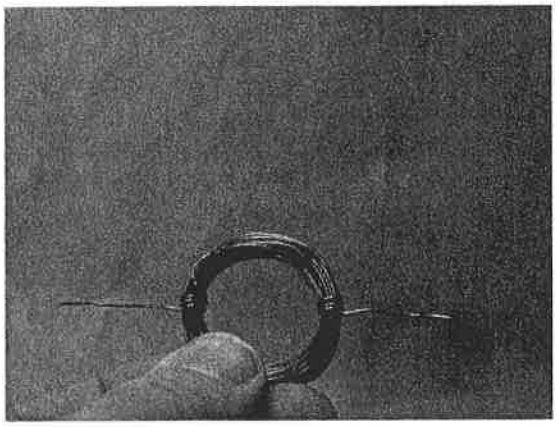
11. Remove the enamel from the bottom portion of the U-shaped slot. To do so, rub it with some sandpaper or a nail file until the copper wire is scraped clean. If any enamel is left in this area, it will prevent the coil from completing the electric circuit when it needs to.



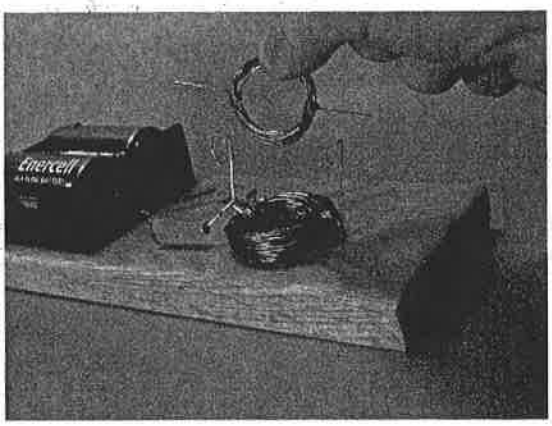
12. Glue the coil to the wood base. Use a silicone adhesive and apply it liberally to the bottom of the coil. Set the coil down onto the wood base in the intended position, and then press lightly to spread the glue onto the wood surface.

13. This coil is made the same way as the one used in the simple motor. The only difference is that this coil is smaller. Wrap the wire around a C cell–sized battery. About 15 to 18 turns is satisfactory. Refer back to the simple motor plans for complete instructions on how to make the coil.





14. The coil for this motor needs to be finely balanced for it to operate. The magnetic field generated by the bottom coil is not as strong as the one produced by a permanent magnet.



15. With the coil scraped and finely balanced, it is ready to run. Put the batteries in place, lay the coil down into the slots, and give it a spin.

    If the motor coil does not spin or if it spins very slowly, it may be too far away from the bottom coil. Bend the 2 wire supports to bring the coil down closer to the bottom coil. The motor will spin faster when the bottom of the motor coil is level with the top of the edge of the lower coil.