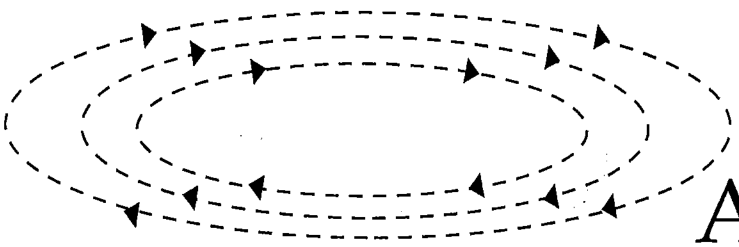
Activity 1

Student Worksheet



A Bonus from Electrical Flow—Magnetism

Background

When you create a closed circuit with a battery, electrons flow through the wires, the bulb lights up and gets hot, and the wires and battery warm up. Besides the chemical reactions going on inside the battery, is anything else happening? It is hard to tell unless you can use some detection device. In this investigation, you will use a compass to detect magnetism. You will use the compass to investigate the relationship between electrical flow and any magnetism that is produced from that flow.

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Topic: electrical circuit
Go To: *www.scilinks.org*
Code: CH003

Topic: magnetic effect
Go To: *www.scilinks.org*
Code: CH004

Concept Goals

- A current-carrying wire produces a magnetic effect (deflects a compass needle) in the region around the wire. That magnetic effect is called *electromagnetism.*
- Electrons move along a wire from the negative end of the battery to the positive end of the battery.
- The direction of the electron flow in a wire determines the direction of the magnetic field around the wire.
- The strength of the magnetic influence (field) around a wire becomes less at greater distances from the wire.
- Magnetic fields (regions of magnetic influence) have direction and "strength."
- The direction of the magnetic field at a particular point in space is the direction a compass needle would point if the compass were located at that point.

Materials

For each group:

- *one ìDî battery (dry cell) and one battery holder*
- *one directional, magnetic compass with a needle that is free to move easily without sticking*
- *one 60-cm piece of #24 enamel-coated (insulated) wire (with sanded ends) or #22 plastic-coated wire (with stripped ends)*

- A left hand is an effective model for showing the relationship between the direction of the magnetic field and the direction of electron flow.

Procedure

1 If you have not used a compass recently, you may want to refresh your memory. The colored or pointed end of the needle usually points approximately toward the Earth's geographic north. Hold the compass out in front of you, away from any metal objects, and note that the colored or pointed end of the needle always points in the same direction, even when you rotate the base or case of the compass.

Move your compass close to an iron or steel object and notice that the compass needle is attracted to the object. It is important, therefore, to keep the compass away from iron or steel objects when you are using it to detect magnetism from other objects. Iron or steel under the desktops can influence the direction in which the compass needle points.

The compass needle is nothing more than a small, light magnet that easily spins about its center when it interacts with other magnets. The compass needle is attracted to iron and steel objects because the needle itself causes those objects to become temporarily magnetized.

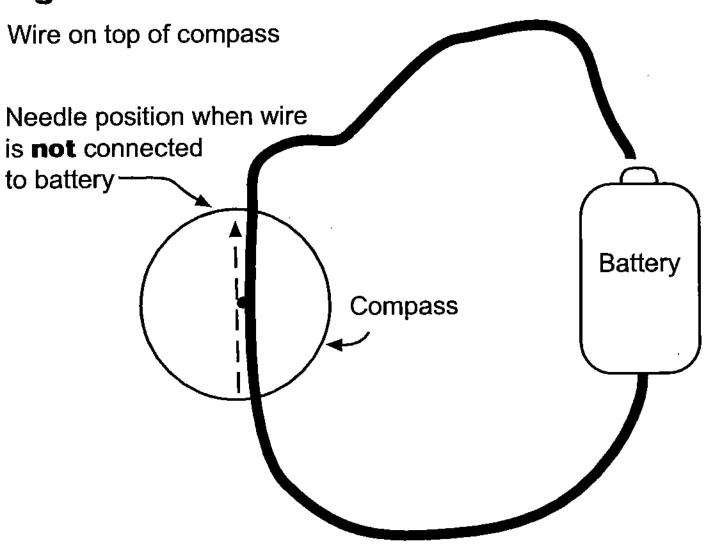
2 In 1820, Hans Christian Oersted, a Danish physicist and schoolteacher, made the observation you are about to make. His discovery set the stage for the development of many modern conveniences, including electrical motors and the generation of electricity from motion.

a Place the compass on the table at least 15 cm away from the battery. Connect one end of the wire to the battery. Place the wire in a straight line directly over the compass and in line with the needle. Briefly touch (no more than two seconds) the other end of the wire to the battery and observe what happens to the compass needle.

Draw an arrow on the compass illustration in Figure 1.1 to show the direction of the needle

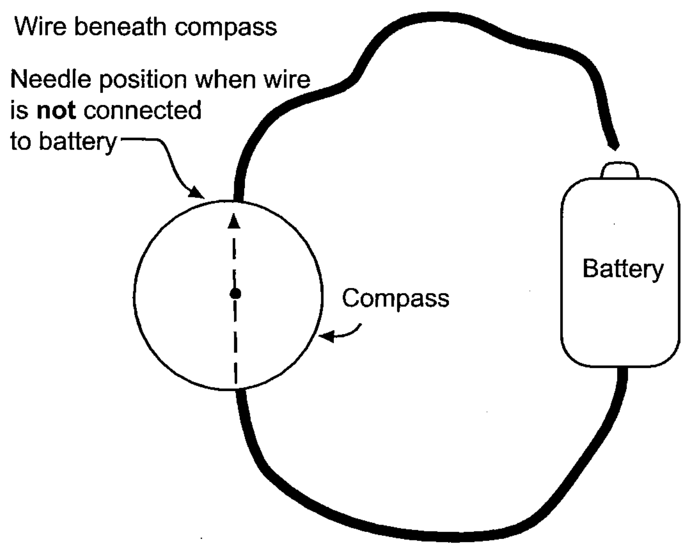
Figure 1.1

Wire on top of compass



when a current-carrying wire is *on top of* the compass. The pointed end of the arrow represents the "north-seeking" end of the needle. Also draw an arrow on the wire showing the direction in which the electrons are moving in the wire. Recall that electrons move along a wire from the negative end of the battery to the positive end of the battery.

Figure 1.2



b Repeat the above activity, but this time place the wire *under* the compass and align the wire with the compass needle. Draw an arrow on the compass drawing (Figure 1.2) to record the direction of the needle when a current-carrying wire is *under* the compass. Also, draw an arrow showing the direction of electron flow in the wire. Remember to keep the electricity flowing in the wire for only two seconds.

c Note the direction in which the needle moved ("deflected") in 2b above. With the wire under the compass and without changing the positions of the compass or the wire, what can you do to make the deflected needle point in the opposite direction? Describe your solution in the space below.

d It should be clear that a current-carrying wire is somehow creating a magnetic influence in the space around it. What can you do to find out how the "strength" of that influence changes with different distances from the wire? Describe your solution, your conclusion about distance and "strength," and how your observations support your conclusion.

e A magnetic field is a region of space in which there is a magnetic influence. There is a magnetic field in the space around a magnet. A compass can detect a magnetic field if the field is strong enough. Because the compass needle is deflected in the region around the current-carrying wire, you can conclude that there is____around a current-carrying wire.

f Magnetic fields have both "strength" and direction at each point in space. The direction is the direction that a compass will point if it is held at that point in space. The magnetic field both above and below a current-carrying wire is: (circle 1 or 2)

1 in line with the wire.

2 across the wire.

g To change the direction of the magnetic field above a wire, you would have to change the ________________ of the electron flow in the wire. Without moving the wire above the compass, you can do this by

____.

h The magnetic field around a current-carrying wire is "stronger": (circle 1 or 2)

1 closer to the wire.

2 farther away from the wire.

3 You can use your left hand as a model of the relationship between the direction of the electron flow and the direction of the magnetic field (the direction the compass would point) created by that flow.

A Left-hand Model

Pretend to grasp the wire with your left hand. Wrap your fingers around the imaginary wire in such a way that your left thumb points in the direction of electron flow (Figure 1.3). Your fingers will then wrap around the wire in the direction of the magnetic field. You can rotate your hand around the wire to see which way your fingers point at any position around the wire (Figure 1.4).

Practice using the left-hand model by answering the following questions associated with Figure 1.5. (circle the correct answer)

a The magnetic field directly *above* the wire at "a" would point:

1 to the left.

2 to the right.

3 straight up out of the page.

4 straight down into the page.

Figure 1.3

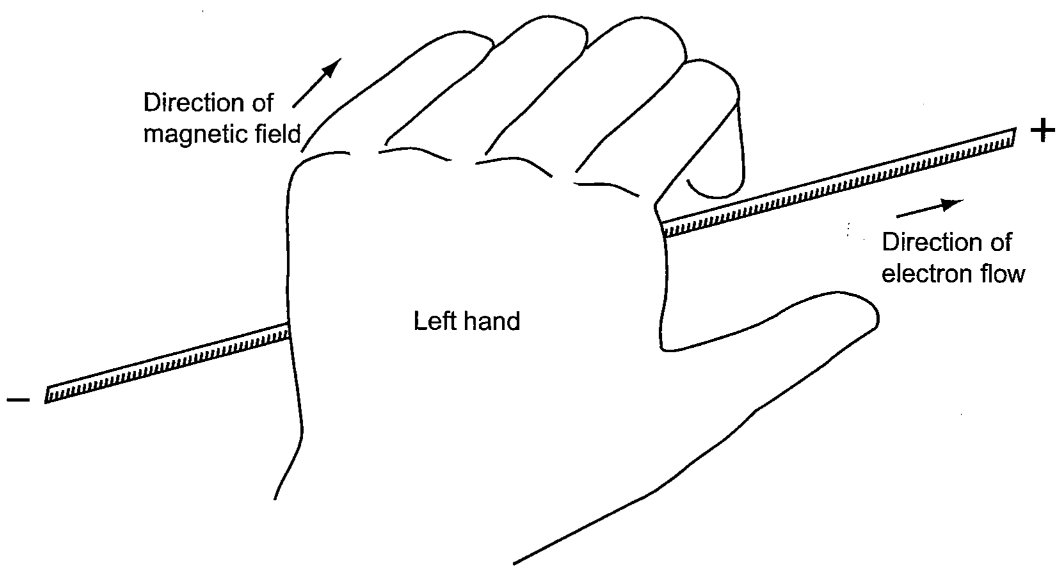


Figure 1.4

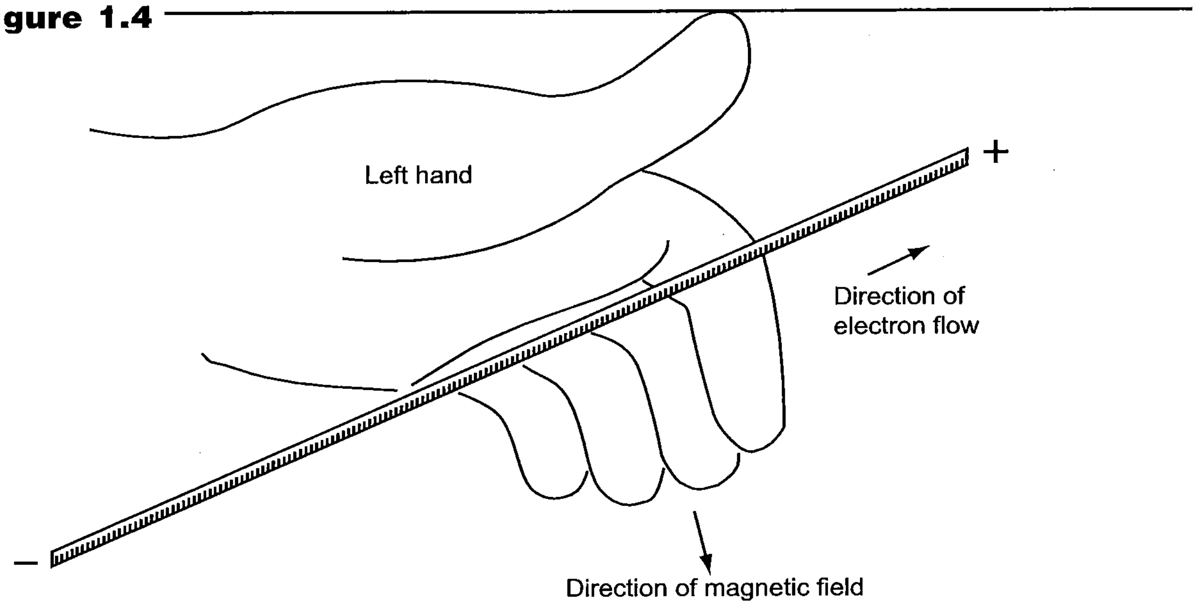
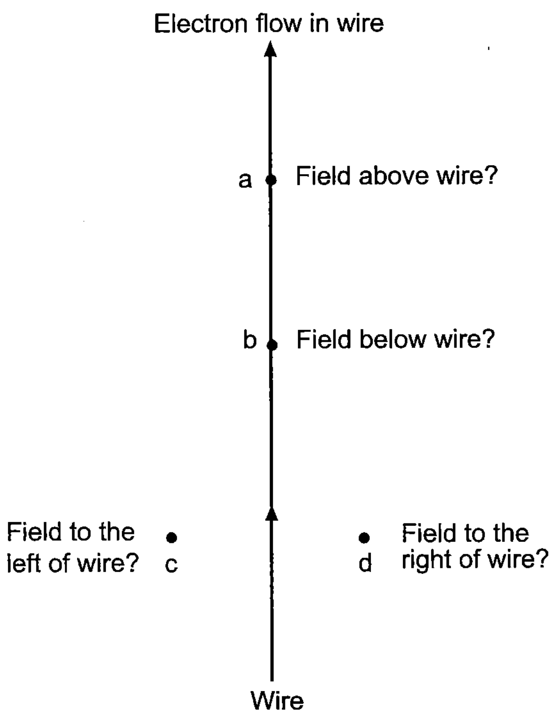


Figure 1.5



b The magnetic field directly *below* the wire at "b" would point:

1 to the left.

2 to the right.

3 straight up out of the page.

4 straight down into the page.

c The magnetic field directly *to the left* of the wire (neither above nor below the wire) at "c" would point:

1 to the left.

2 to the right.

3 straight up out of the page.

4 straight down into the page.

d The magnetic field directly *to the right* of the wire (neither above nor below the wire) at "d" would point:

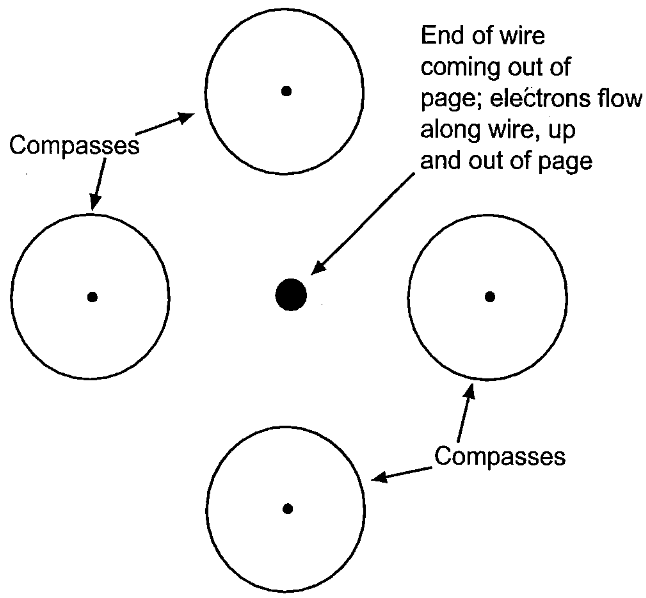
1 to the left.

2 to the right.

3 straight up out of the page.

4 straight down into the page.

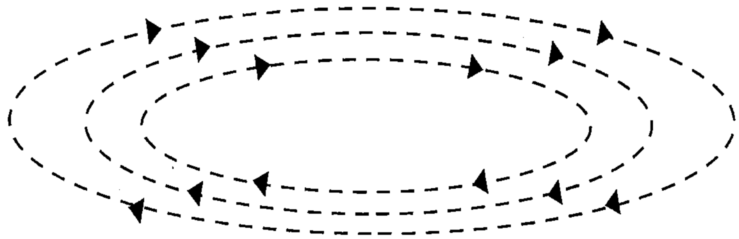
Figure 1.6



e Observe Figure 1.6 and assume that the dot in the center is the end of a wire that is coming out of the page. Further assume that electrons are flowing along that wire out of the page directly upward from the page. Use your left-hand model to determine the direction of the compass needle (direction of the magnetic field) at each of the compass points around the wire. Draw the compass needles in the four compasses and use the pointed head of the arrow as the "north-seeking" end of the compass needle.

Activity 2

Student Worksheet



Coils and Electromagnets

Background

Hans Christian Oersted was probably very excited about his discovery that a current-carrying wire produces a magnetic effect in the region around that wire. Perhaps he realized that current-carrying wires could produce very strong magnetism that may be able to exert forces to turn wheels and accomplish work. All of modern day electric motors depend on the production of magnetism from current-carrying wires. In this activity, you will investigate how to make the magnetism from current-carrying wires stronger. In the next activity you will use an electromagnet to make an electric motor.

Topic: electromagnet
Go To: *www.scilinks.org*
Code: CH005

Concept Goals

- A coil of wire that carries a current produces a stronger magnetic field than just a straight wire that carries the same current.
- A piece of iron (e.g., a nail) placed in a coil that carries a current will become magnetized by the coil.
- A piece of magnetized iron in a coil that carries a current will produce a stronger magnetic field than just the coil alone.
- An electromagnet is a magnet that is produced by a coil that carries an electrical current.

Materials

For each group:

- *one ìDî battery (dry cell) and one battery holder*
- *one 80-cm piece of enamel-coated (insulated) wire (with sanded ends) or bell wire (with stripped ends)*
- *one 20-cm piece of enamel-coated (insulated) wire (with sanded ends) or bell wire (with stripped ends)*
- *three plastic drinking straws*
- *two pieces of masking tape*
- *one large, steel paper clip (4.8 cm x 1 cm)*
- *twenty large, steel paper clips chained together*
- *one steel or iron nail (8ñ10 cm long)*
- *one beaker, or a foam or plastic cup*
- *one light bulb in its socket*
- *scissors*

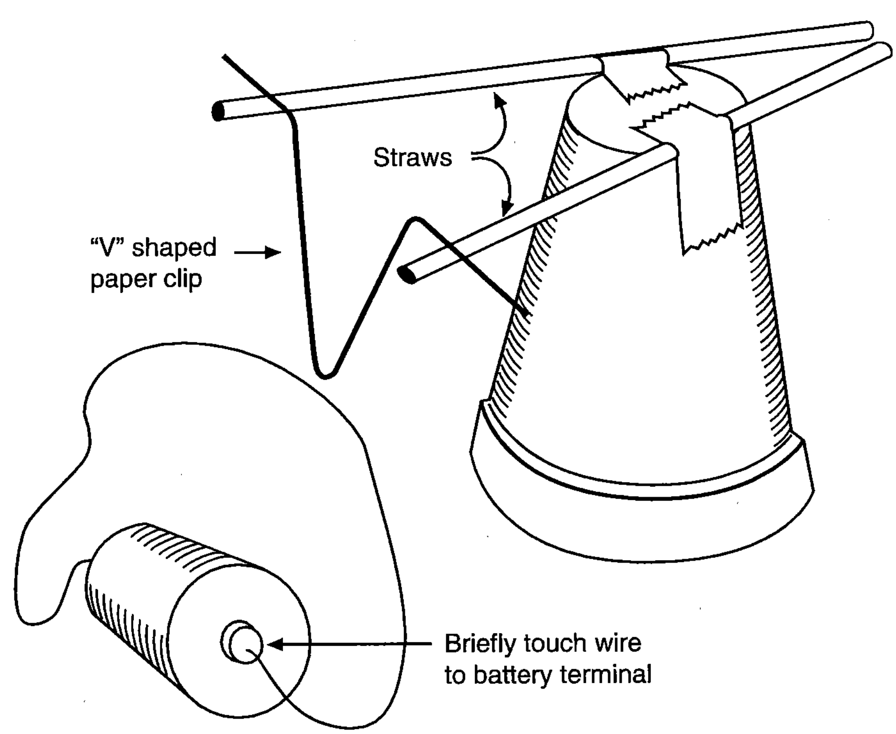
- The strength of an electromagnet increases as the number of wraps in the coil increases.
- The strength of an electromagnet decreases as the electrical current in the coil decreases.

Procedure

1 In the last activity, you deflected a compass needle with a current-carrying wire. Because a current-carrying wire acts like a magnet (it produces a magnetic effect in the region around it), perhaps the wire will attract iron objects just as a regular permanent magnet does.

a Tape two plastic drinking straws to the bottom of an overturned cup or beaker. The ends of the straws should be about 8 cm apart. Open the large paper clip and bend it into a "V" shape as shown below. Place the "V" shaped paper clip on the "arms" of the drinking straws so that it easily moves back and forth (Figure 2.1).

Figure 2.1



b Attach one end of the 80-cm wire to one end of the battery. Use your fingers to stop the paper clip from swinging back and forth. Move the wire very near the bottom part of the "V" (again, see Figure 2.1). Don't touch the paper clip. When the wire is very close to the stationary paper clip, *briefly* touch the other end of the wire to the battery to send a current through the wire. Is the paper clip attracted to the current-carrying wire? Write your answer below.

Caution

A short circuit is created when the wire is attached to the battery. The wire gets hot. Do not allow the ends of the wire to touch the battery for more than two seconds at a time.

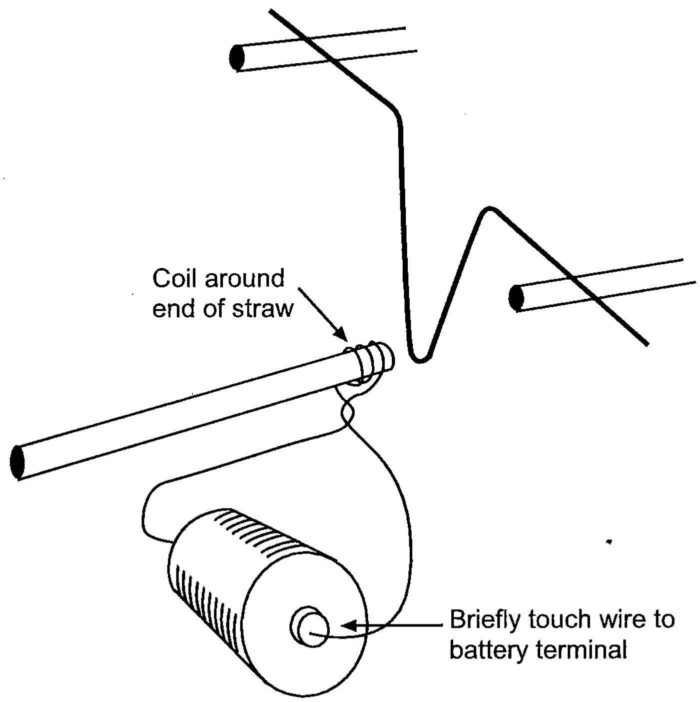
c Starting about 8 cm from one end of the wire, wind the wire around your index finger. Be careful not to wind too tightly. Stop winding when you are about 8 cm from the other end of the wire and slip the coil of wire off your finger. Keep the coil together.

Attach one end of the wire to one end of the battery. Again use your fingers to stop the paper clip from swinging back and forth. Move the coil very near the bottom part of the "V." Don't touch the paper clip. When the coil is very close to the stationary paper clip, briefly touch the other end of the wire to the battery to send a current through the coil. Is the paper clip attracted to the current-carrying coil? How does the coil's attraction compare to the attraction of a single strand of wire? Write your answers below.

d Disconnect the wire from the battery and unwrap the coil of wire. **Do not pull on the ends of the wire to straighten out the coil; this will produce a kinky mess.**

Next, starting about 8 cm from the end of the wire, wrap the wire around a drinking straw (Figure 2.2). Try to keep all the coils within a 1-cm section of the straw. Keep the coil rather tight but do not wrap so tightly that the straw is crushed. Stop wrapping when there are about 8 cm of wire left. Next, use the scissors to cut one end of the straw close (0.3 cm) to the coil.

Figure 2.2

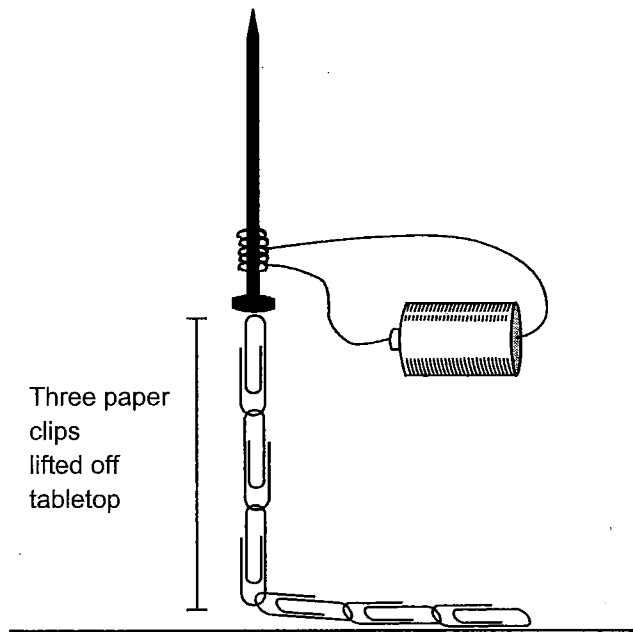


Connect one end of the wire to one of the battery terminals. Stop the "V" from moving. Move the coil near the end of the bottom of the "V." *Briefly* touch the other end of the wire to the other terminal of the battery to send a current through the coil. Describe below the extent to which the current-carrying coil attracts the "V" paper clip.

Next, place the nail into the end of the straw near the coil. Hold the head of the nail near the "V" and briefly send a current through the coil. How does the coil-and-nail's attraction of the "V" compare to the coil's attraction alone? Write your answer below.

2 When you wrap an insulated current-carrying wire around an iron or steel object, you create an electromagnet. As you found in step 1d above, the iron or steel can greatly increase the magnetic force exerted on nearby objects. The magnetism created by the coil turns the nail into a temporary magnet. For electromagnets to be of any use, they must be able to create rather large magnetic forces. The question arises: How can we increase the strength of an electromagnet?

Figure 2.3



Challenge: Use the nail, the battery, and the chain of 20 paper clips to investigate how the number of coils wrapped around the nail determines the strength of the electromagnet (the number of paper clips lifted off the table).

Keep the coils near the head of the nail.

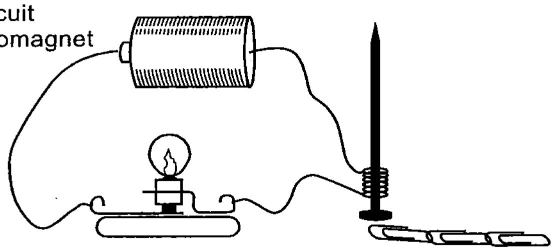
Stretch out the chain of paper clips on the table.

Use the head of the nail to pick up the first paper clip in the chain. Smoothly move the nail (with the first paper clip attached) over the second paper clip and try to pick two paper clips off the table (Figure 2.3). Keep moving down the chain to see how many paper clips the electromagnet will pick off the table. Keep the nail vertical and in line with the string of paper clips that have been picked off the table.

Now wrap some more coils around the nail and follow the same steps as above.

Conclusion: In the space below, describe the relationship between the number of coils in an electromagnet and the strength of the electromagnet.

Figure 2.4



3 Construct an electromagnet that will consistently pick up at least three paper clips from a chain of paper clips on the tabletop.

Next, place a light bulb and socket in the circuit, as shown in Figure 2.4. Use the electromagnet to try to pick up at least three paper clips along the chain.

a Describe below how the bulb in the circuit with the electromagnet influenced the strength of the electromagnet.

b When the bulb was placed in the circuit with the electromagnet, the bulb provided resistance to the flow of electricity and caused the electrical flow to be reduced in all parts of the circuit. In other words, the bulb reduced the rate of electrical flow or current through the electromagnet. How does the current (rate of electrical flow) in an electromagnet determine the strength of the electromagnet?

Activity 3

Student Worksheet

Making an Electric Motor—Electromagnetism in Action

Background

The last activity focused on electromagnetism and factors that determine the strength of magnetic interaction. Scientists and engineers have used their knowledge of electromagnets to create simple electromagnetic devices (doorbells, switches, circuit breakers, sound speakers, etc.) that are very much a part of our everyday lives. One of the more complex, ingenious, and useful devices is the electric motor. Electric motors are all around us, turning VCR tapes, CDs, computer disk drives, can openers, toothbrushes, refrigerator and air conditioner pumps, drills, saws, fans, and more. Each electric motor turns because of electromagnets and electromagnetic interaction. In this activity, you will build an electric motor out of common materials, including plastic drinking cups, wire, batteries, plastic drinking straws, and magnets. Although the motor you build will not be able to accomplish much, it should provide you with a basic understanding of how real electric motors work. You will learn that "timing is everything." Furthermore, as you persist in getting your motor to work, you may understand better the persistence and problem solving required to create a useful product that works reliably.

Your teacher will either provide you with the rotor, flopper switch, and penny switch for this activity or guide you through constructing them.

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Topic: electric motor
Go To: *www.scilinks.org*
Code: CH008

Materials

For each group:
For Part 1ótheìstrobeî light

- *one rotor on its stand (see Figure 3.1)*
- *one flopper (with washer) (to make a flopper, see page 42)*
- *one penny switch (with wires attached) (to make a penny switch, see page 39ñ42)*
- *two 1.5-volt dry cells in dry cell holders*
- *one light bulb in a socket*
- *two 15-cm wires*
- *masking tape*

Concept Goals

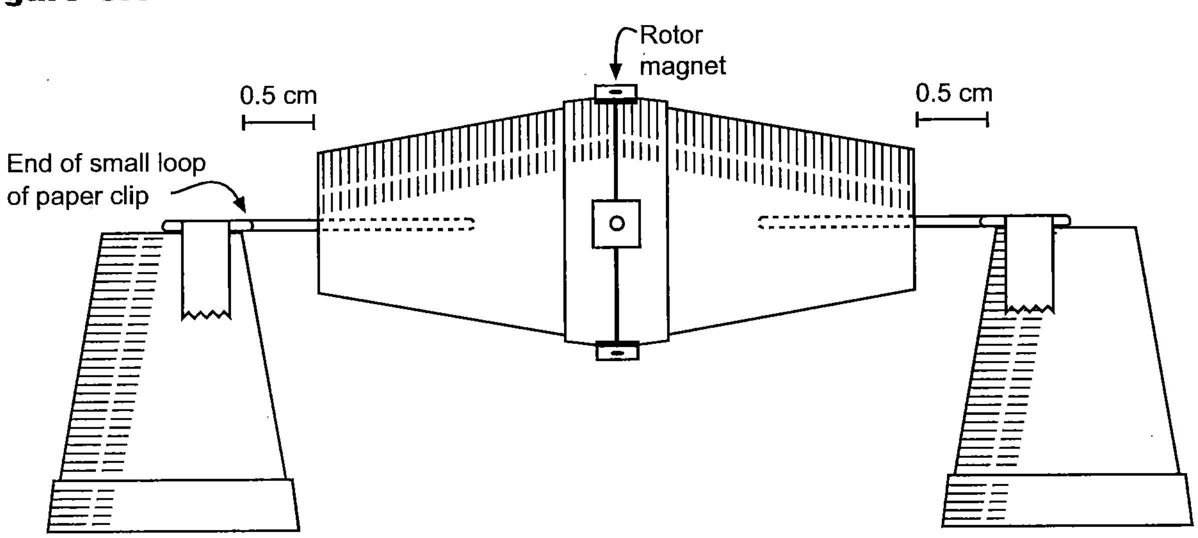
- An electric motor can be built from available simple materials (magnets, wire, batteries, cups, etc.).
- Electric motors work because of the interaction between electromagnets or because of the interaction between electromagnets and permanent magnets.
- Rotors are what move in motors and the rotors are pushed around because the magnets on them interact with other magnets in the motor.
- For electric motors to work, electromagnets must turn on and off at just the right times.

Part 1—Building a "Strobe" Light

1 Set up the rotor as shown below (Figure 3.1). Leave at least a 30 x 30-cm area of empty tabletop in front of the rotor. Position the cup stands so that the rotor easily rotates or spins, but does not move sideways by more than a centimeter. When you have properly placed the rotor and stands, tape the cup stands to the tabletop.

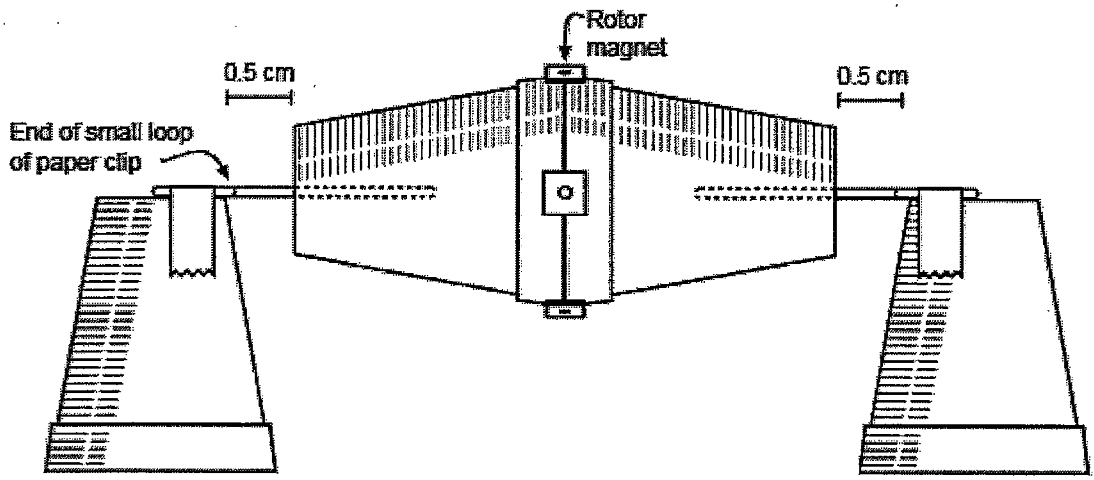
2 Adjust the position of the washer on the flopper so the flopper tips up slightly on the magnet end (Figure 3.2).

Figure 3.1

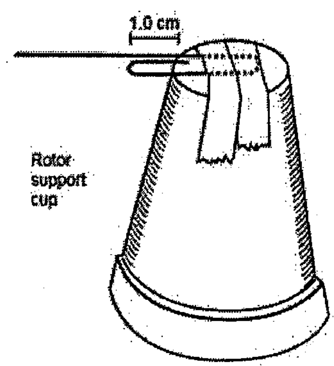


Activity 3: Making an Electric Motor

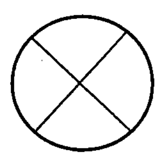
Instruction Supplement – Making the Rotor



1. To make stands for the rotor, open and straighten the large loops of two large paper clips. Tape these clips to the bottoms of two cups (see diagram). Make sure there is about 1 cm of the small loop that extends beyond the bottom of the cup. The end of the small loop will prevent the rotor from rubbing against the stand.



2. Take 2 other cups, and draw a cross on the bottoms by drawing 2 "diameter lines" at angles to one another in order to find the centre point of the bottom.



3. Have your teacher make holes in the centres, using a hot paperclip.

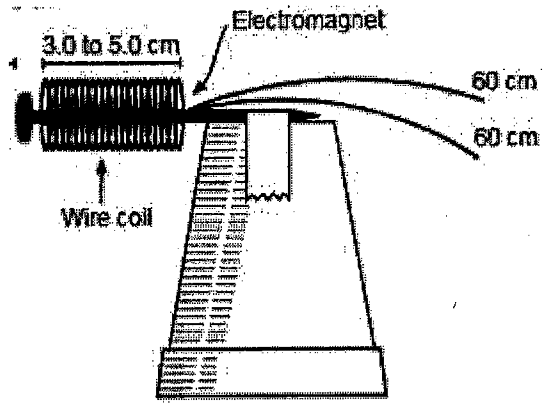
4. To indicate where to place the permanent magnets on the rotor, draw a square with sides equal to the diameter of the top of the cup. Draw diagonal lines from corner to corner in the square. Place the cup upside down inside the square and mark the rim where the lines cross the rim.

5. Use a hot glue gun to glue the rim of the marked rotor cup to the rim of the other rotor cup. Make sure you can see the marks when the two cups are glued together.

6. After the glue on the rotor cups is dry, glue the four rectangular magnets to the rims of the cups at the marked positions. Make sure that the same pole (north or south) faces outward on all four magnets. In other words, the outward facing side of each magnet should repel the outward facing side of all the other magnets.

7. Assemble the pieces as in the diagram at the top of the page.

Instruction Supplement – Making the Electromagnet



1. Cut a 5m length of magnet wire.

2. About 60 cm from one end of the wire, start wrapping most of the wire around the 3-cm section of nail near the head of the nail. Wrap it **tightly** and **neatly**. Do not wrap the last 60 cm of wire.

3. Twist the two 60-cm lengths of wire together to keep them from unraveling from the coil.

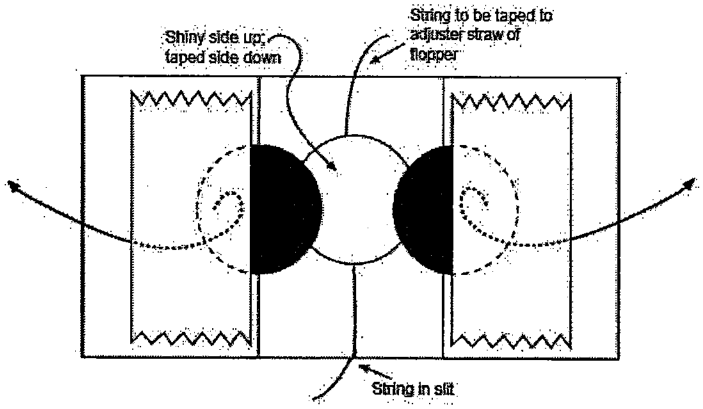
4. Tape the nail to the bottom of a cup.

5. Sand the enamel off the last 3 cm of each wire.

6. When the electromagnet is used, you will have to tape the cup with the electromagnet securely to the tabletop so that the head of the nail is about 1 cm from a magnet on the rotor, but that is not necessary yet.

Note: This task is the fastest to complete. Your job now is to help the other 3 members of your team create their rotor, penny switch, and flopper.

Instruction Supplement – Making the Penny Switch



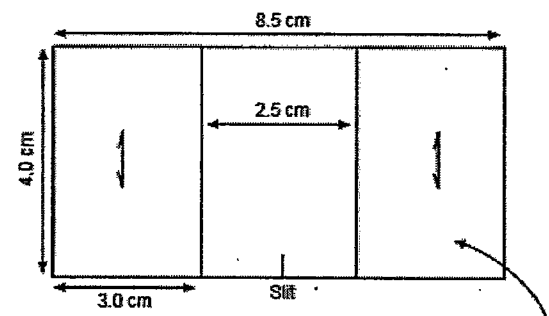
1. Cut a rectangular piece of cardboard that is 4cm x 8.5cm

2. Cut 2 rectangular pieces of cardboard that are 3cm x 4cm

3. Staple the two smaller pieces onto the bigger piece as shown. Make sure there is 2.5cm of space between the two smaller pieces

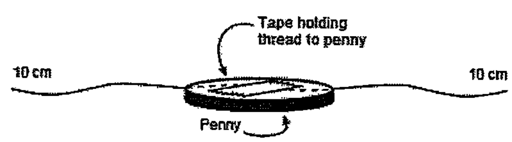
4. Cut a small slit in the middle of the long side of the base.

5. Cut 2 60cm pieces of magnet wire, and sand the enamel off of the last 3 cm of each end.

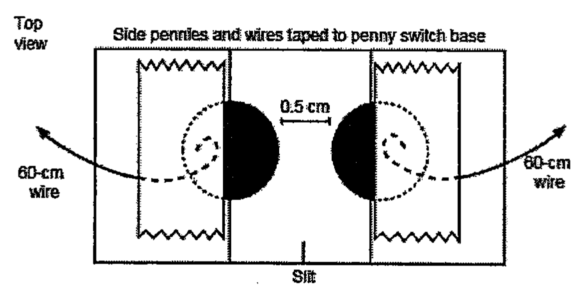


6. Obtain 3 clean pennies, and sand both sides of all of them.

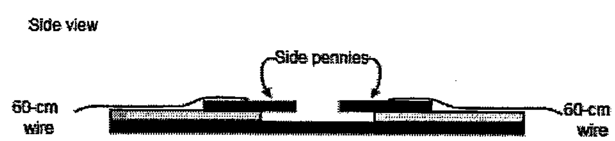
7. Cut a 20cm piece of thread, and tape the mid-point of it to one of the pennies.



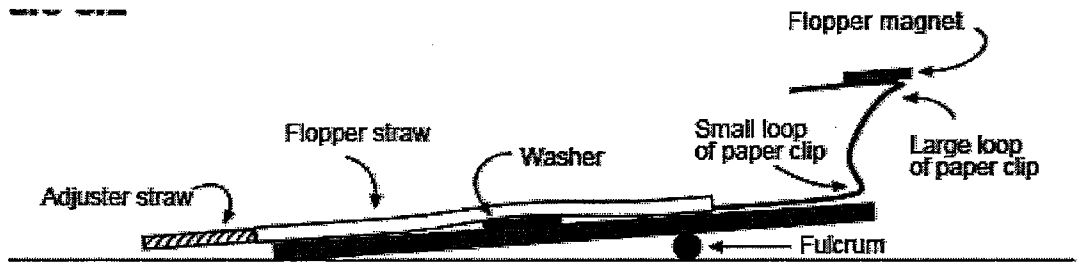
8. Use masking tape to tape the wires to the two side pennies (without the string) and to the cardboard as shown. The side pennies should be 0.5 cm apart. Press the masking tape tightly to the wires and pennies to ensure solid contact between the wires and pennies.



9. Insert the middle penny (with the string) beneath the two side pennies. The middle penny should have its shiny side facing up and its taped side facing down. Insert the string into the slit and adjust the string until the middle penny is in about the position shown in the diagram at the top of the page. The string in the slit keeps the penny in place. The other end of the string will be taped to the adjuster straw of the "flopper" later.

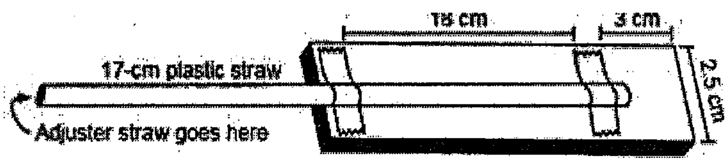


Instruction Supplement – Making the Flopper



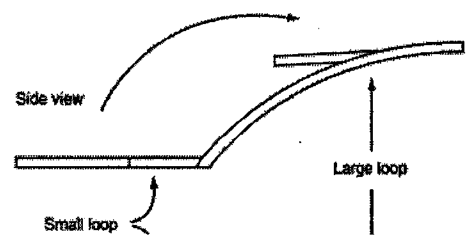
1. Cut a 18cm x 2.5cm rectangular piece of cardboard.

2. Tape a 17-cm section of plastic drinking straw (flopper straw) to the cardboard as shown. Start the straw 3 cm from one end of the cardboard.



3. Cut an 8-cm length of plastic drinking straw (adjuster straw), crimp the one end, and insert the crimped end about 1–2 cm into the extended end of the flopper straw. The adjuster straw should fit snugly inside the flopper straw, but should be able to turn inside the flopper straw.

4. Bend open the large loop of a large paper clip as shown.



5. Tape the small loop end of the paper clip to the end of the flopper as shown in the diagram at the top of the page.

6. Tape a rectangular magnet onto the large loop of the paper clip by taping underneath, not over, the magnet. Make sure that the side facing upward repels the magnets on the rotor. **It is important to have the flopper magnet and each of the rotor magnets repel one another.**

7. Place a washer under the flopper straw about midway between the edges of the tape holding the straw to the cardboard.

8. Cut a 12cm section of plastic drinking straw (fulcrum), and place it under the flopper until the flopper just about balances. Tape the fulcrum to the underside of the flopper. Move the washer forward or backward along the flopper to make adjustments.

3 Rotate the rotor and hold it so one of its magnets is as close to the table as possible (directly under the middle of the rotor). Slide the magnet end of the flopper under the rotor so the magnet of the flopper is directly under the lowest rotor magnet. The rotor magnet and the flopper magnet should repel one another and the magnet end of the flopper should tip down. The objective is to get the magnet end of the flopper to tip down when a rotor magnet is at the lowest point and to tip up after a rotor magnet moves by the lowest point. It may be necessary to bend the paper clip holding the flopper magnet in order to move the flopper magnet closer to the rotor magnet. After making adjustments, tape both sides of the fulcrum to the table. Make a final test by rotating the rotor. The magnet end of the flopper should move down when a rotor magnet comes close to it and then should move back up after a rotor magnet goes by (Figure 3.3).

Materials ...cont'd.

For Part 2ó the electric motor

- *one electromagnet on its cup stand*
- *all the above materials except one 15 cm wire and the bulb and its socket*
- *additional materials as listed in the Teacherís Guide, pages 38ñ39*

Figure 3.2

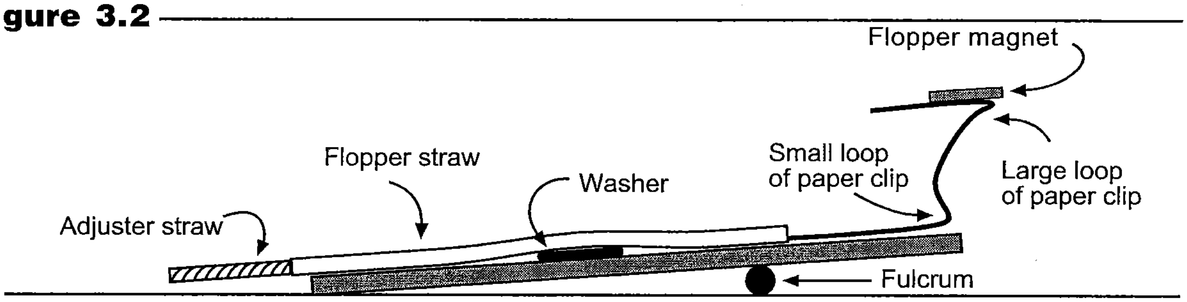


Figure 3.3

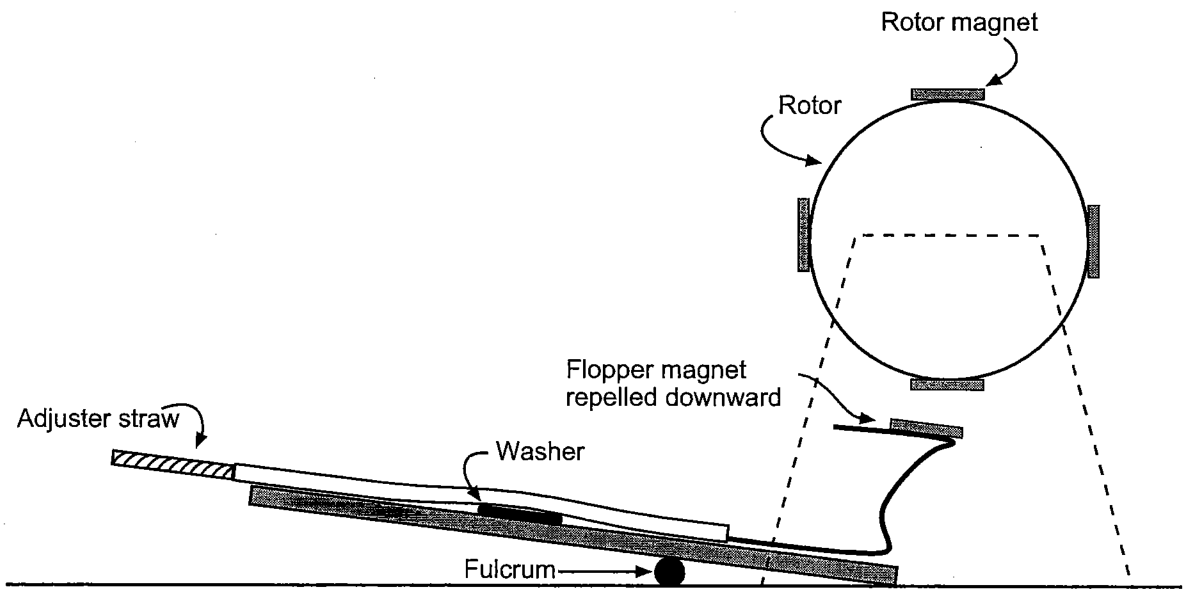
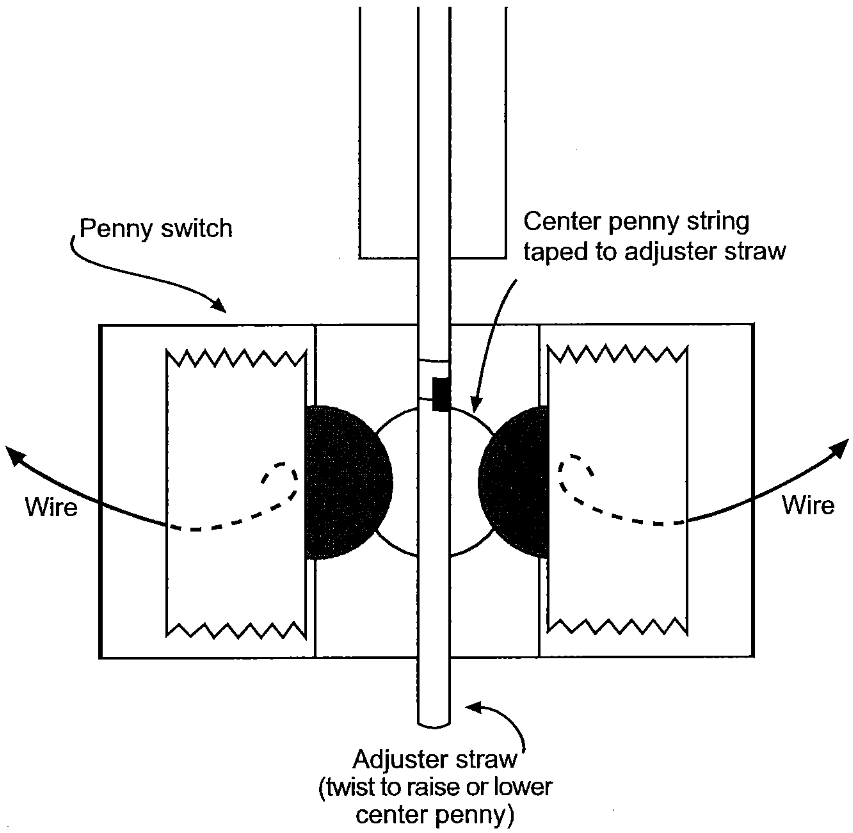


Figure 3.4

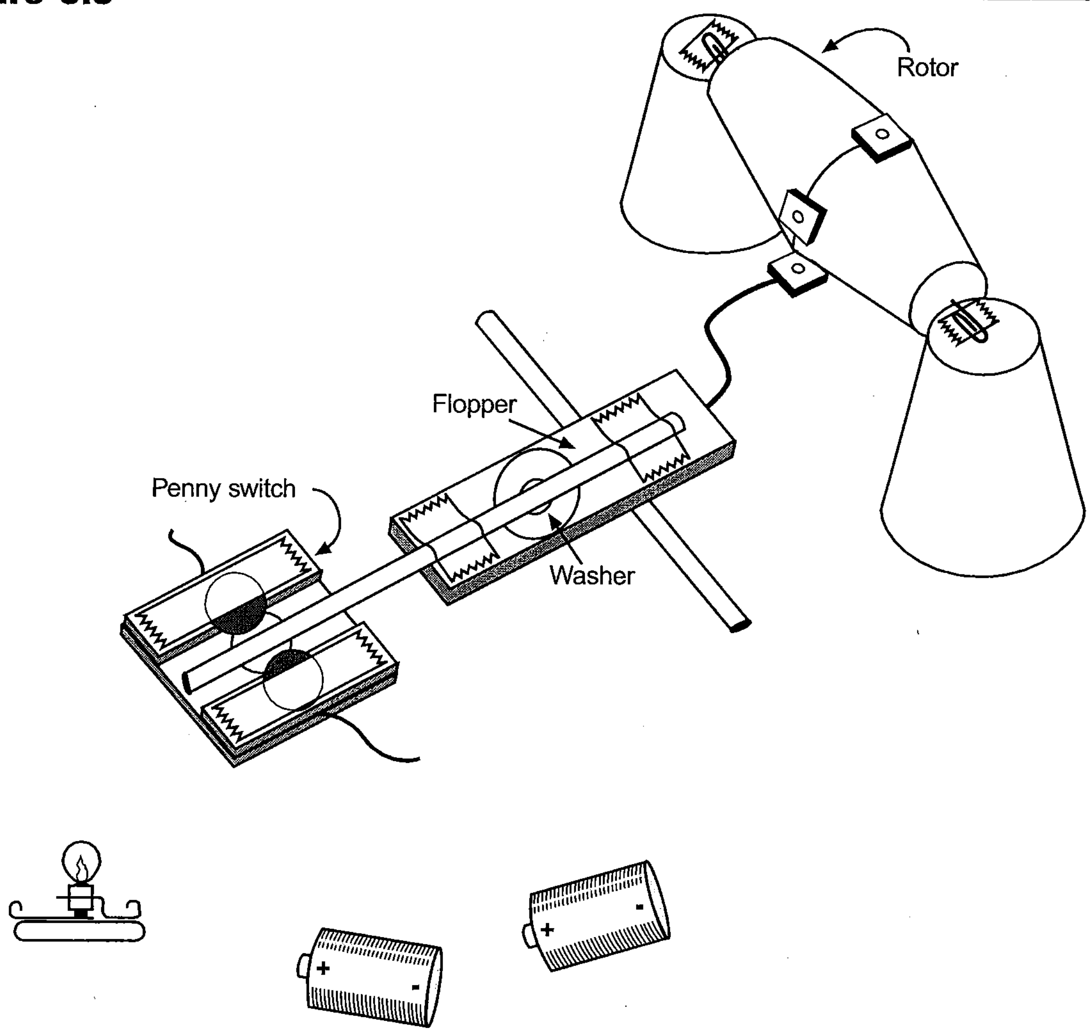


4 Move the penny switch under the back portion of the flopper as shown in Figure 3.4. One edge of the adjuster straw should be midway between the side pennies of the penny switch. Make sure the shiny side of the middle penny is facing up. Use a very small piece of tape to tape the string of the middle penny to the middle of the adjuster straw. Make sure there is at least 3–4 cm of string between the middle penny and the straw. Twist the adjuster straw to shorten or lengthen the penny string. When everything is in place, tape both sides of the penny switch to the table.

5 **Challenge**: Your set-up should look something like Figure 3.5. Create a circuit so that the light bulb blinks on and off as the rotor is turned. Do not remove the wires from the penny switch. Try not to move the flopper. Use the adjuster straw to raise and lower the middle penny of the penny switch. Draw "wires" on Figure 3.5 to show how you connected the various parts to create the "strobe" light.

6 When the rotor magnet is directly over the flopper magnet, what does the flopper magnet do? What does the switch end of the flopper do? Write your answers here.

Figure 3.5



7 When a rotor magnet is directly over the flopper magnet, what happens to the middle penny of the penny switch? Write your answers here.

8 When a rotor magnet is directly over the flopper magnet, is the penny switch on (conducting electricity through it) or is the penny switch off?

9 When there is *no* rotor magnet directly over the flopper magnet, describe what happens to the flopper magnet and describe what happens to the switch end of the flopper.

10 When *no* rotor magnet is directly over the flopper magnet, describe what the flopper is doing to the middle penny of the penny switch.

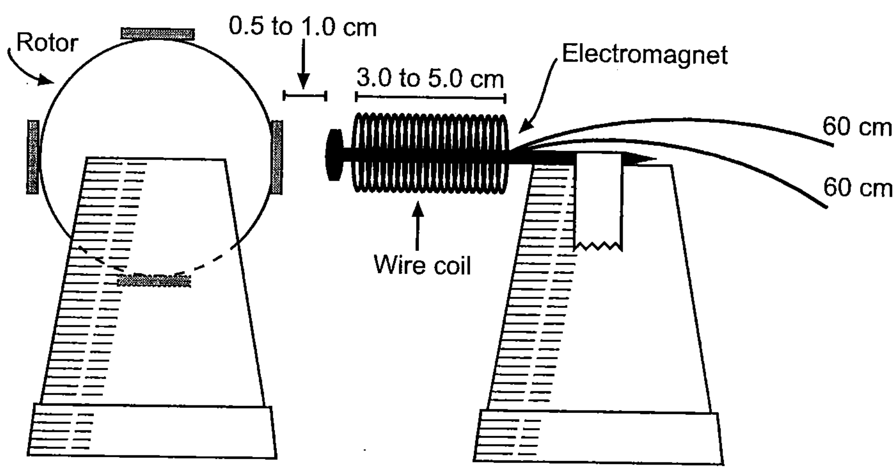
11 When *no* rotor magnet is directly over the flopper magnet, is the penny switch on (conducting electricity through it) or is the penny switch off?

Part 2— Building an Electric Motor

12 Put away the bulb and its socket. Place the electromagnet so that it is as close as possible to the rotor magnets but does not touch any of the rotor magnets as they pass by (Figure 3.6). Thoroughly tape the electromagnet cup to the table. Any movement of the cup and electromagnet will reduce the operation of the motor.

13 Challenge: Arrange the batteries and wires so that when the rotor is gently spun, the rotor keeps spinning due to the interaction of the rotor magnets and the electromagnet. Arrange your set-up so that the electromagnet repels each of the rotor magnets. Draw "wires" on Figure 3.7 to show how you connected the objects to get the motor to work.

Figure 3.6

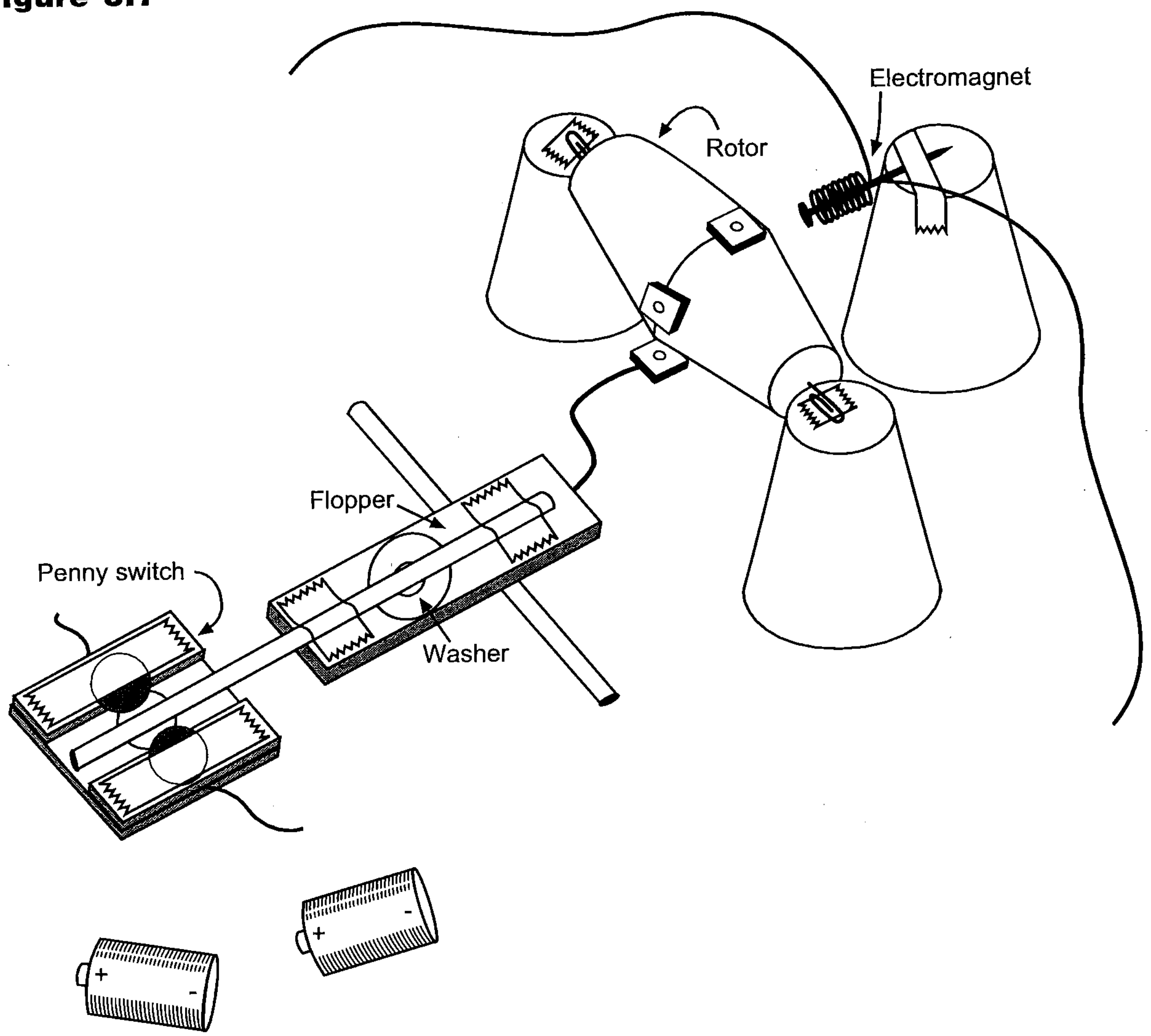


Some notes and hints:

- The electromagnet should repel the rotor magnets. If this does not occur, change the direction of the current through the electromagnet by turning the batteries around or by switching the electromagnet wires in the circuit.
- Adjust the position of the washer on the flopper. You might try to get the motor to work without the washer.
- Try spinning the rotor in different directions. One direction may work better than the other direction.
- Try spinning the rotor slowly or giving the rotor a gentle, but fast spin.
- Twist the adjuster straw to raise and lower the middle penny of the penny switch.
- All electrical contacts must be good. You may have to use sandpaper to clean the contact points. Make sure the enamel has been removed from the ends of all wires.
- Make sure your batteries are fresh. Do not leave a closed circuit on for very long. A closed circuit through an electromagnet will quickly wear out the batteries.

14 Consider what is happening when a rotor magnet is directly over the flopper magnet. When this occurs, another rotor magnet is very close to (almost directly in front of) the electromagnet. The penny switch should be on and electricity should be flowing through the electromagnet. Recall that the current-carrying electromagnet and the rotor magnets have the same poles facing each other. In this position, describe below what the electromagnet is doing to the rotor magnet near it.

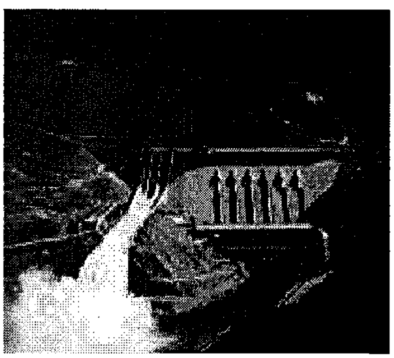
Figure 3.7



Build Your Own Hydroelectric Generator

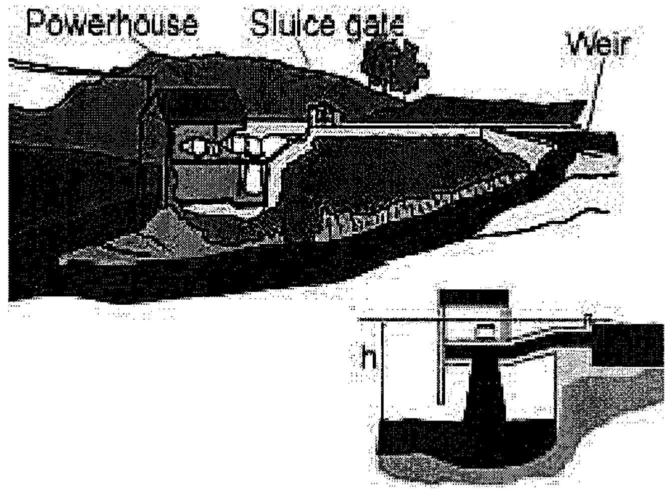
Micro-hydro Basics

Most machines that make electricity need some form of mechanical energy to get things started. Mechanical energy spins the generator to make the electricity. In the case of hydroelectricity, the mechanical energy comes from large volumes of falling water. For more than 100 years, the simplest way to produce the volumes of falling water needed to make electricity has been to build a dam. A dam stops the natural flow of a river, building up a deep reservoir behind it. However, large dams and reservoirs are not always appropriate, especially in the more ecologically sensitive areas of the planet.



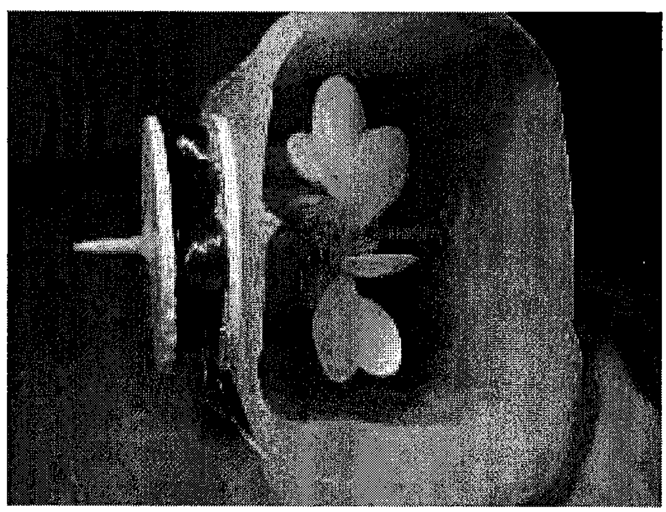
Canada and many other countries depend on large-scale hydro developments for electricity.

For making small amounts of electricity without building a dam, the small-scale hydroelectric generator is often the best solution, especially where fast-flowing streams on steep slopes are close by. A small-scale hydro system usually consists of an enclosed water wheel or turbine, which is made to spin by jets of high-velocity water. The water is taken from the stream and moved down slope to the turbine through a long pipe called a penstock. Water flowing through the penstock picks up speed, and is directed at the blades of the turbine by nozzles. The turbine spins continuously, as long as there is water to drive it. The turbine is connected to an electrical generator, and the electricity is then available for running appliances or charging batteries. The spent water is returned to the stream. This kind of system is called a "micro-hydro" system, "run-of-stream hydro" or "low-impact hydro."



Micro-hydro systems can provide clean, environmentally friendly electricity in rural communities.

In this activity, you will use plastic spoons to build a model of a simple micro-hydro system. It generates surprising amounts of electricity, provided you have a supply of pressurized water, such as from a lab sink. This model closely resembles real micro-hydro designs, and can produce enough electricity to light a small light bulb.



The completed micro-hydro turbine.

Making electricity

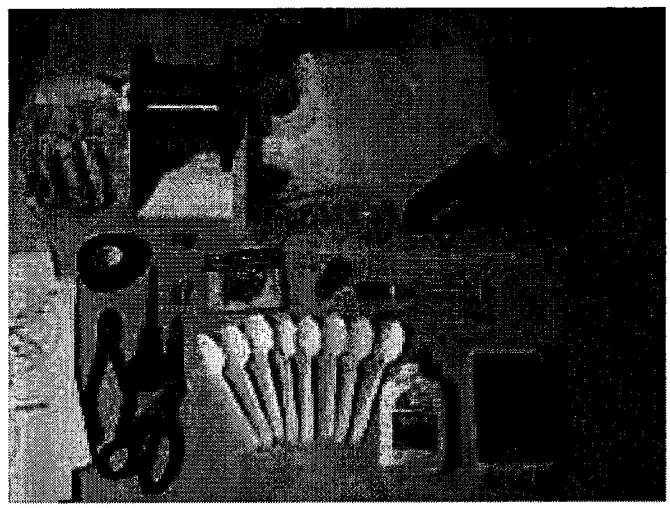
We are surrounded by hundreds of appliances that use electricity to do work. But what is electricity? Basically, electricity is a flow of electrons in a metal wire, or some other conductor. Electrons are tiny particles found inside atoms, one of the basic building blocks of all matter. We call the flow of electrons through any conductor a "current of electricity."

Each electron carries a tiny negative charge. When electrons move through a conductor, they produce an invisible field of magnetic force, similar to that found around a magnet. The strength of that field depends on how many electrons are in motion. You can concentrate this field by winding the wire in which the electrons move into a tight coil with many turns. This causes many more electrons to be in motion in a small space, resulting in a stronger field. If you then place a piece of iron in the middle of the coil, the electromagnetic field will turn the iron into a powerful magnet.

While it is true that electrons moving through a conductor produce a magnetic field, the reverse is also true. You can make electrons move in a wire by "pushing" them with a moving magnet, which is how an electrical generator works. Electrical generators usually contain powerful magnets that rotate very close to dense coils of insulated wire. The coils develop a flow of electrons that becomes an electrical current when the generator is connected to an electric circuit.

You will be building an electrical generator as part of this project. It uses moving magnets to create a current of electricity in coils of wire. This generator is technically called an alternator because the electrons move back and forth in the wire, rather than flowing in just one direction as they do from a battery. A meter connected to the wire would show that the charge of the wire switches or alternates between positive and negative as the electrons change directions. Such an electrical current is called alternating current or AC. Household electrical current is alternating current. Appliances have to be specially designed to use it. The other type of current is called direct current, because the electrons move in one direction only. Most battery-powered appliances such as calculators and portable CD players use direct current.

Build It!



Safety Precautions

Electric drills can cause serious eye and hand injuries. Eye protection is required, and leather gloves are recommended when drilling small parts such as corks. A cork borer can be used as a substitute but it also has risks for injury.

Hot glue guns can cause superficial burns. Be sure glue guns are warmed up only when needed, and unplugged immediately after. Hot glue can stick to skin and clothing.

Tools

- Electric drill, with ¼" drill bit
- Scissors
- Electrical tape
- Ruler
- 10 cm (3.5 inch) nail
- Hot glue gun
- White glue or glue stick
- Pencil sharpener
- Magnetic compass
- Wire cutters
- Gloves
- Safety glasses

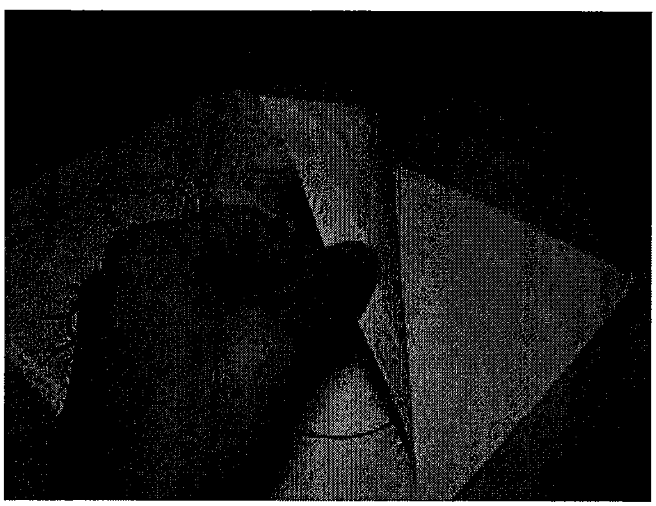
Materials

- Paper Templates: Please download the following templates separately and print according to the printing instructions.
  Micro-hydro template (74K)
  Important: Printing Instructions
- 4L plastic jug (rectangular style, from vinegar, windshield washer fluid, or similar-see illustration)
- 10 plastic spoons
- 1 large cork (3.5 to 5 cm)
- Enameled magnet wire, 24 gage (approx. 100 m)
- Foamcore or heavyweight corrugated cardboard (approximately 22 cm by 30 cm)
- 6 mm (1/4 inch) wooden dowel (20 cm long)
- 4 ceramic or rare earth magnets (18mm or larger)
- clear vinyl tubing (6 cm long, ¼" inside diameter)
- 4 brass paper fasteners

A. Prepare the Disks

The generator we are building has two basic parts-the rotor and the stator. The stator is the part that remains stationary and has coils of wire to collect electricity. The rotor is the part that moves. It is equipped with powerful magnets that will induce current of electricity in the coils.

1. Glue the template sheet.
Be sure to spread a thin layer of glue evenly over the entire back of the template.



Cover the back of the template with a thin, even layer of glue.

2. When the glue has dried, use the scissors to cut the rotor and stator disks from the cardboard sheet. Carefully trim the edges.

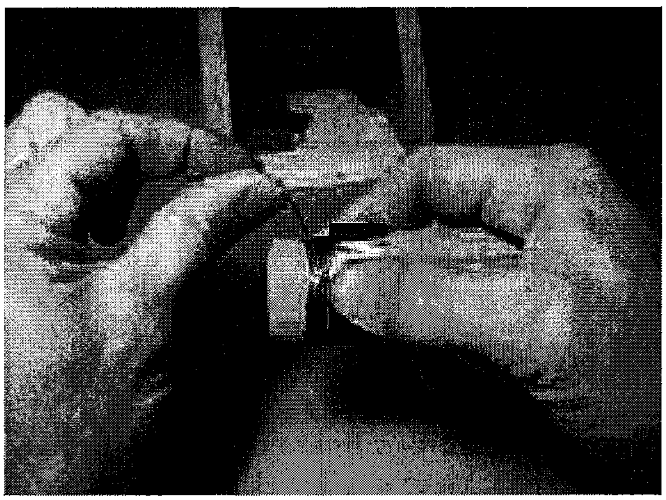
3. Using a sharp nail, punch a small hole through the rotor disk at its exact center, as shown. Using scissors, make a larger (1 cm) hole at the center of the stator disk.

B. The Stator

1. Prepare a jig for winding your coils by cutting a 3 cm by 16cm piece of cardboard, folding it in half and securing with a small piece of electrical tape.

2. Cut 8 short (4 cm) strips of electrical tape and set these aside.

3. Leaving a lead of about 10 cm, start winding the first coil on the jig. Wrap the wire neatly onto the jig, forming a tight coil, as shown below. Use 200 wraps or turns.



4. Carefully slip the coil off the jig and secure it using two pieces of the electrical tape you set aside in step 2 above.

5. Using a small patch of emery cloth or sand paper, remove the enamel insulation from the ends of each lead, exposing about 1 cm of bare wire. Be sure the wire is completely bare!

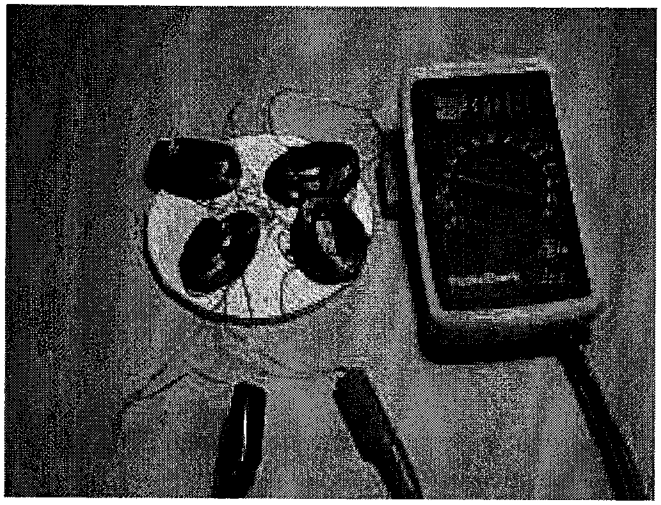
6. Repeat steps 1 through 5 to make three more coils.

7. Lay the coils loosely on the disk in the position shown by the template. Arrange the coils so their windings alternate between clockwise and counter-clockwise, as shown on the template. THIS IS VERY IMPORTANT! Arrange and connect the coils so that an electron would follow the path shown by the arrows, starting with the counterclockwise coil on the left hand side.

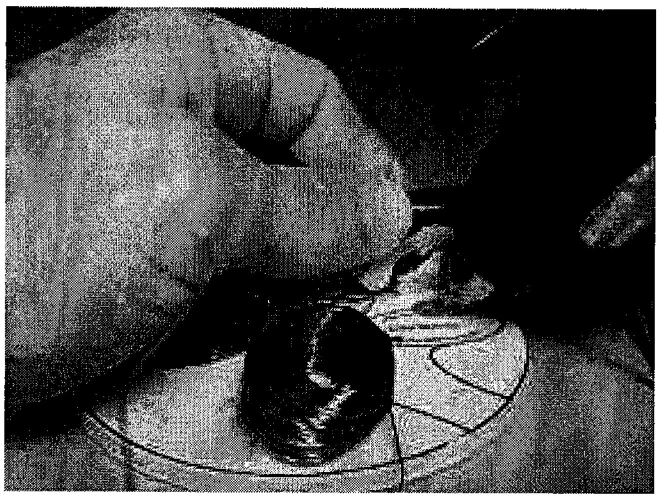
8. When you are sure you have them arranged correctly, connect the coils by twisting the bared ends together, covering the connections with small pieces of electrical tape.

9. Check your connections: Set your multi-meter for measuring electrical resistance (ohms). If your connections are good, there should be little resistance to the movement of electrons, and the meter should produce a reading of about 10 ohms or less. To check this, touch or connect the probes to the two free ends of the wires from the coils. If the coils are not properly connected, the reading will be a very large number, or infinity.

10. Once you are confident the coils are properly positioned and connected, glue them to the stator disk. Lift each coil up a little and apply a large blob of glue to the template where the coil touches. Let the glue solidify before gluing the next coil.



Check to make sure you have good connections between the coils.

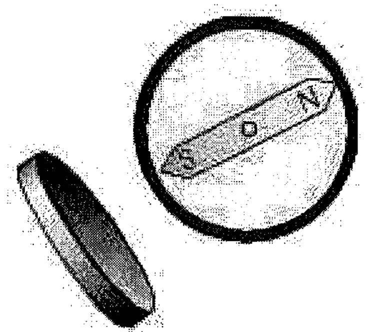


11. Using scissors, cut 4 slits through the cardboard between the magnets as shown on the template. These slits will be used to fasten the stator to the plastic container later.

C. The Rotor

1. Obtain 4 magnets.

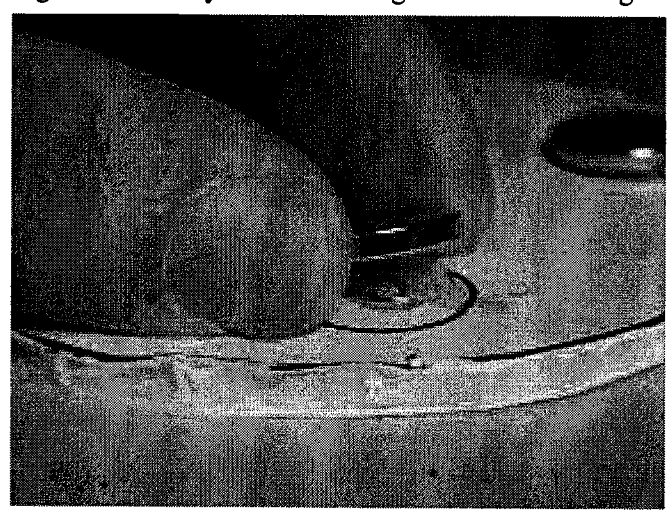
   Using the magnetic compass, determine the polarity of each face. Remember, likes repel, and apposites attract. Attach them each to a washer. 2 North-up, and 2 South-up



Checking the polarity of one face of a magnet using a compass.

2. Warm up your hot glue gun, and prepare to attach the magnets and washers to the rotor disk. The magnets must be arranged so that their upward-facing polarity alternates (i.e. N-S-N-S). Their position and polarity are indicated on the template.

3. Squeeze some hot glue on the bottom of the washer. Quickly place the magnet with its washer onto its marked spot, as shown below. Allow the glue to solidify before moving onto the next magnet.



4. Repeat this for the 3 remaining magnets, making sure to alternate N and S poles as you go.

D. The Shaft

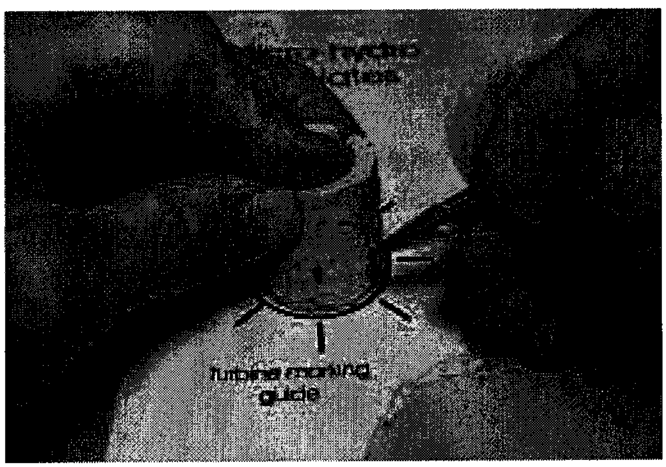
1. Cut the dowel down to 20cm in length.

2. Using a pencil sharpener put a point on each end of the wooden dowel (it is not necessary to make a sharp point-blunt will do).

E. The Turbine

1. Find the centre of the cork, and mark it. Drill a ¼" (6mm) hole through it.

2. Center the wide end of the cork on the marking guide on the template page, and mark the cork with a pen or pencil, as shown below.



3. Place the cork wide-end down on the table. Use scissors to carve shallow slits into the cork where the spoons will be inserted. Make sure they are all in line with one another along the centre of the side of the cork.

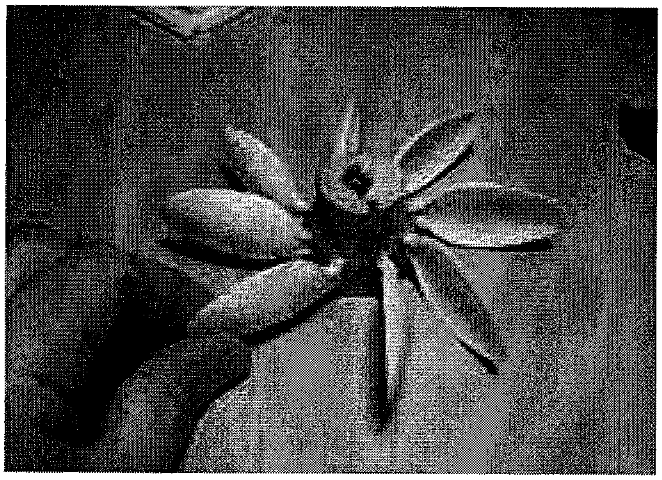
4. Obtain 8 plastic spoons. Using the wire cutters, cut the spoon handles leaving a 1 cm stem on the bowl of the spoon.

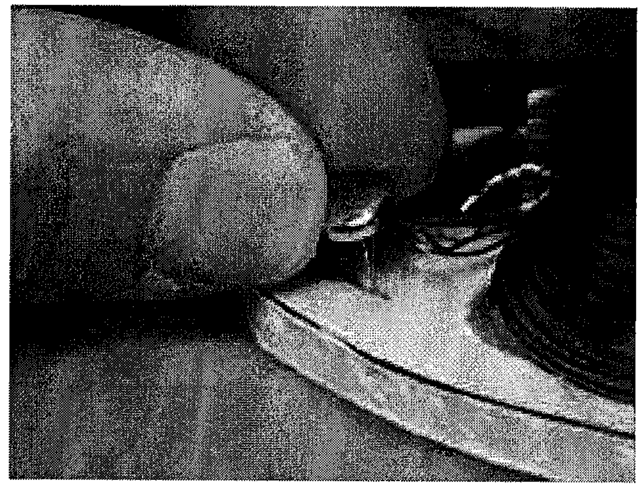
5. Be sure the glue gun is warmed up and that you have a glue stick or two handy.

6. Insert the first spoon into one of the slits you carved into the side of the cork. Push the stem of the spoon into the cork to a depth of about 1 cm.

7. Repeat step 6 with the remaining 7 spoons. Adjust the angle and depth of the spoons so they are evenly spaced and all project from the cork at the same angle.

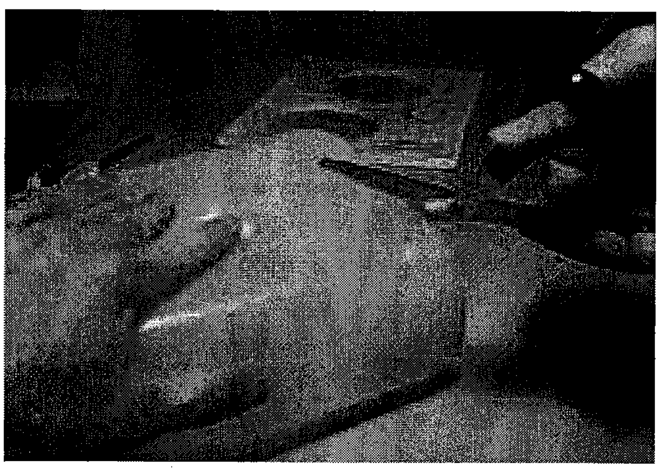
8. When you are satisfied with your turbine, add some hot glue to each spoon to secure it on the cork.





F. The Housing

1. Obtain the plastic container and tear off any labels that might be attached to the sides. Using scissors or a utility knife, cut part of the bottom off, as shown in the photo below.



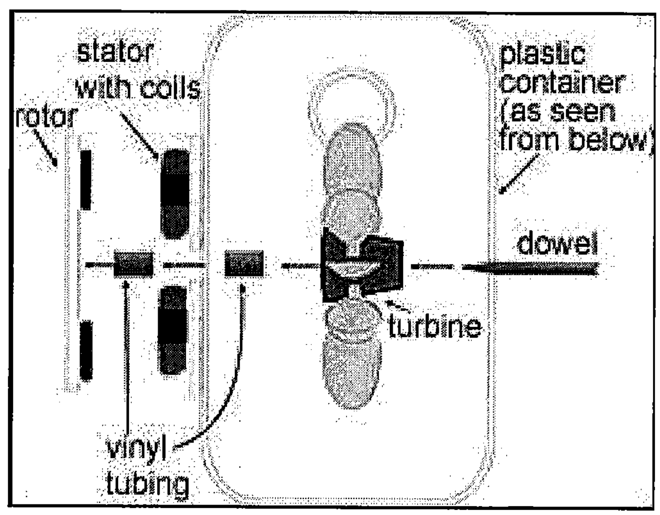
2. Using a ruler, find the center of the side as accurately as you can. Mark this point with the permanent marker. Repeat for the other side.

3. At the mark on each side of the container, drill a ¼" (6mm) hole through the plastic. Expand the hole slightly, but rotating the drill around in the hole.

4. Lay the stator with its attached coils on the side of the container so that its center hole is over the hole in the container. Push a nail through each slit on the stator disk to mark the locations of these slits on the side of the plastic container.

5. Using scissors, poke 4 small holes on the side of the container, corresponding with those on the stator disk.

6. Using the brass fold-over tabs, securely mount the stator disk to the side of the plastic container. Bend the tabs flat on the inside of the container, as shown.

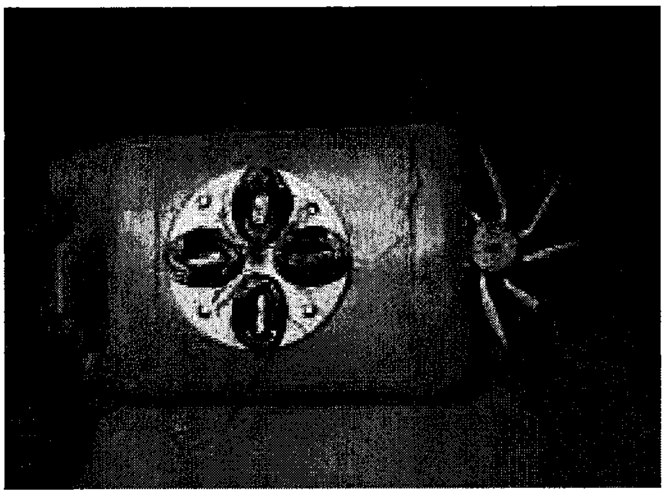


G. Final Assembly

1. With scissors, cut the vinyl tubing into two small lengths, each 1 cm long.

2. Slide the shaft into the plastic container through the hole in the stator. Inside the container, slide one piece of tubing onto the shaft.

3. Position the turbine inside the container so the spoons face the neck of the bottle.

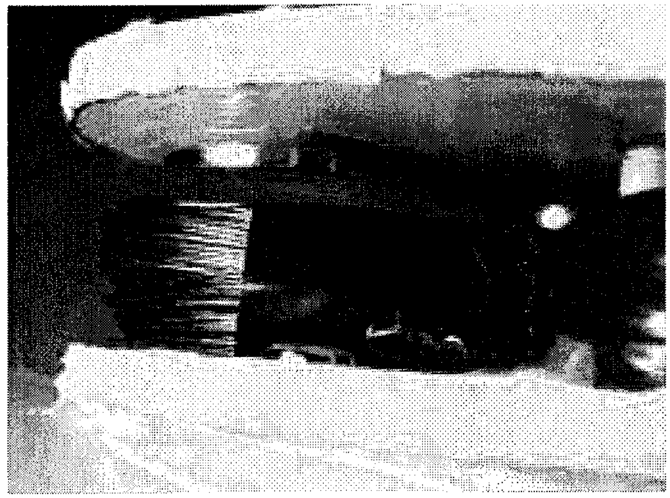


4. Push the shaft through the turbine's cork. Work the cork and the tubing down the shaft so the shaft comes out the other side of the container and projects by about 4 cm.

5. Adjust the position of the turbine so the spoons line up with the neck of the container.

6. Adjust the position of the tubing so that it comes close to but does not touch the inside of the container.

7. Slide the second section of tubing over the end of the shaft as shown. The two pieces of tubing will help to keep all parts of the turbine positioned correctly when it spins. Spin the shaft to be sure it turns without binding, and that the turbine does not strike the inside of the container as it spins.

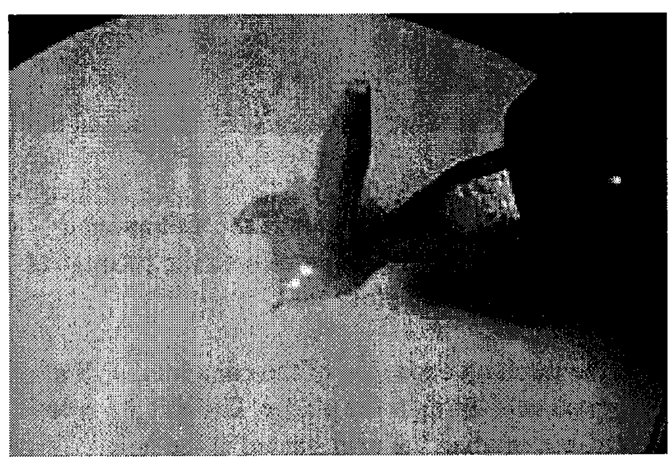


The magnets should be close to, but not touching the coils as they turn.

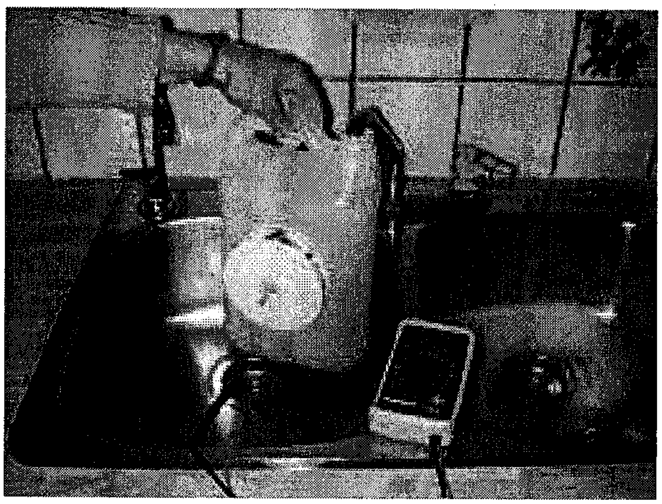
8. Slide the rotor disk onto the shaft. Position it so that the magnets come to within 2 or 3 millimetres of the coils. Spin the shaft to be sure the magnets do not strike the coils.

9. Check the rotor disk to see that it spins true. Turn the shaft slowly and note any wobble. Adjust the angle of the disk on the shaft as necessary.

10. When the rotor disk spins without wobbling, fix it in position with hot glue applied to the point where the shaft passes through the reinforcing disks.



Reinforce the rotor disk with hot glue.



Test It!

If all has gone well with your construction, this turbine should be able to produce significant amounts of electricity, depending on the speed of the water striking the spoons.

1. Place the neck of the plastic container under a faucet and turn on the water. The rotor should spin quickly!

2. Connect your micro-hydro turbine to a multi-meter and set the dial to read volts of alternating current. Measure the voltage generated by the operating turbine.

Questions

1. What variables in a micro-hydro system could you change to get more electricity from it?

2. In what locations in Canada or other parts of the world would micro hydro be a good choice for clean energy?

3. What practical problems would you encounter in setting up and running a micro-hydro system in a rural area ?

4. Why are micro-hydro systems seen as better for the environment compared with large-scale dams?

5. Use the Internet to locate distributors and manufacturers of micro-hydroelectric components. Use the search terms "micro-hydro", "pelton wheel", and "run of stream."

Notes: