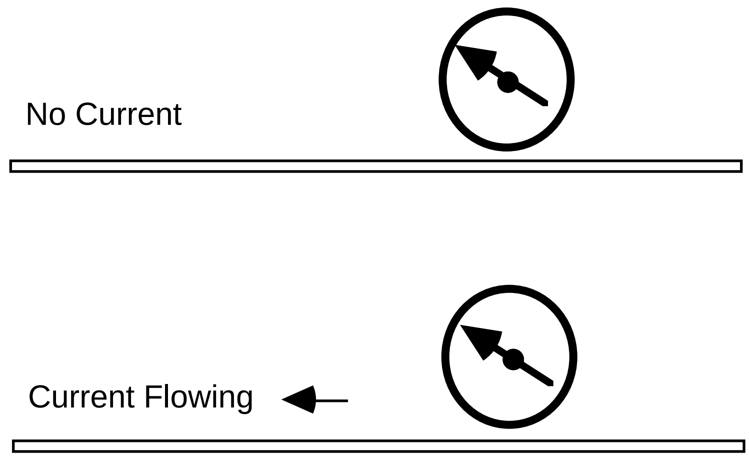
ELECTROMAGNETISM

PROBLEM PRESENTATION / EXPLORATION

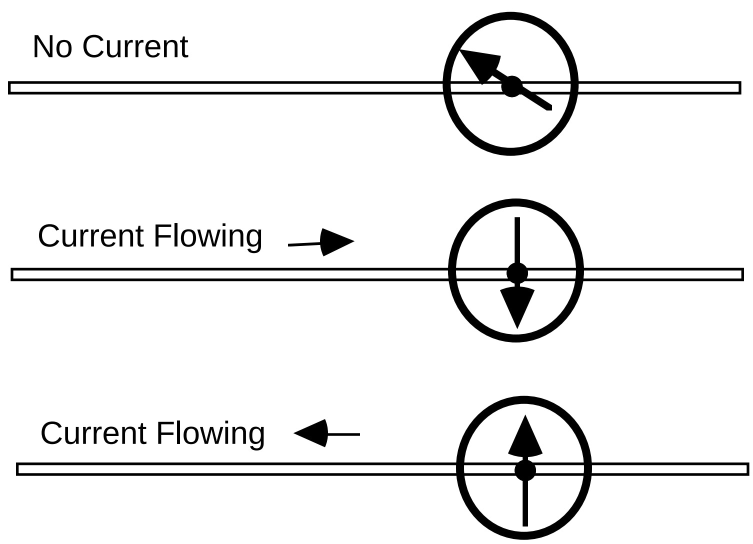
A. Oersted's Discovery (*Magnetism can be produced from electricity*)

1. Place a loop of copper wire flat on the table. With the wire remaining flat on the table attach the two ends to the terminals of a dry cell battery. Place a small compass next to the wire. Observe the compass. Do not leave the wire hooked to the battery for more than a few seconds. It will get hot. [There should not be any motion of the compass needle.]



3. One day in 1820 Oersted was lecturing a physics class when he noticed a wire lying **above** a compass. When the current flowed through the wire the compass needle was deflected. This chance observation led him to a powerful discovery.

   a. Hook up the wire to the battery again. This time hold the wire above the wire that is resting flat on the table. Note what the needle on the compass does. [It deflects at an angle perpendicular to the wire.]

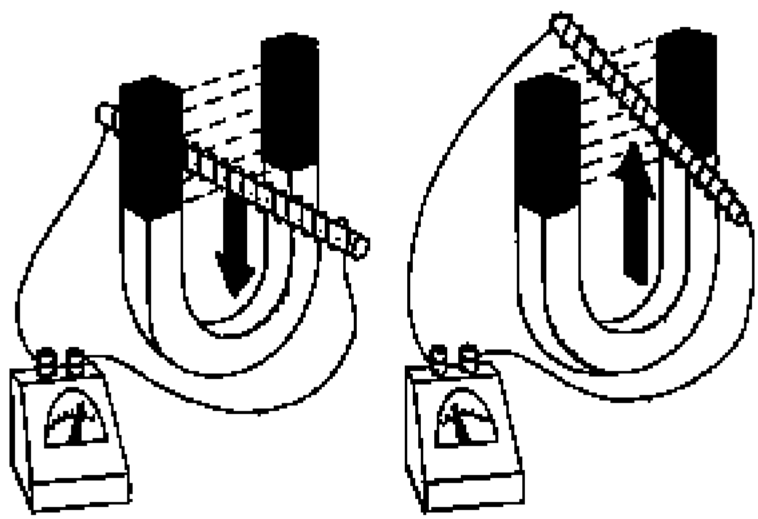


   b. Once again hold the compass above the wire that is resting flat on the table but reverse the connections of the wires to the terminals of the battery. Note what the needle on the compass does. [This time it deflects the other direction but still perpendicular to the wire.]

4. From these experiments we see that **an electric current flowing through a wire gives rise to a magnetic field whose direction depends upon the direction of the current**.

B. Henry and Faraday's Discovery (*Electricity can be produced from magnetism*)

1. In 1831 Faraday (England) and Henry (USA) reasoned that if magnetism can be produced from electricity, electricity should be able to be produced from magnetism.
2. A galvanometer is a sensitive device that will register the direction that electrons are flowing through it. Hook a piece of copper wire to the two terminals of the galvanometer. Move a horseshoe magnet up and down so that the wire can cut the magnetic lines of force between the poles of the magnet. Note the reading of the galvanometer. [When the magnet is moving downward the deflection will be one way; when the magnet is moving upward the deflection will be the other way. If the magnet is not very strong, a deflection may not appear to occur. In the Concept Invention portion of this lesson this will be remedied by using a wire with many loops so that more lines of force will be cut.]
3. Set the horseshoe magnet on the table so that the legs are pointing upward. Move the same wire and galvanometer back and forth cutting the magnetic force line between the poles of the magnet. Note the reading of the galvanometer. When the wire is moving downward the deflection will be one way; when the wire is moving upward the deflection will be the other way.]



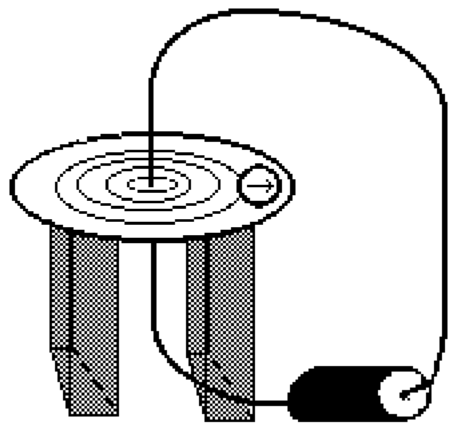
4. In neither case was any source of voltage needed to cause electrons to flow. The production of voltage and current depends only on the relative motion between the conductor and the magnetic field. **Voltage is induced and electrons flow whether the magnetic field of the magnet moves past a stationary conductor, or the conductor moves through a stationary magnetic field**.

CLASS RESPONSE / CONCEPT INVENTION

A. Electromagnetism

1. Set two books on end side by side about 20 cm apart. Use the point of a pencil to poke a tiny hole in the middle of a paper plate and place it on top of the books.

2. Thread a strip of insulated copper wire through the hole so that the wire passing through the plate is perpendicular to the plate. Loop the wire back down passing by the outside of the plate. The two ends of the wire should be hanging below the plate
3. Sprinkle some iron filings on the plate. Place a small compass on the edge of the plate.
4. Attach the ends of the wire to a dry cell battery on the table. The end coming from under the plate should be attached to the negative terminal.
5. Set a small compass on the inside edge of the plate. Observe the compass needle. Tap the plate gently and observe the filings. As in the first section of this lesson don't leave the wire hooked to the battery more than a few seconds at a time. [The compass deflected so that it was perpendicular to the wire. The iron filings moved to arrange themselves in concentric circles around the wire.]

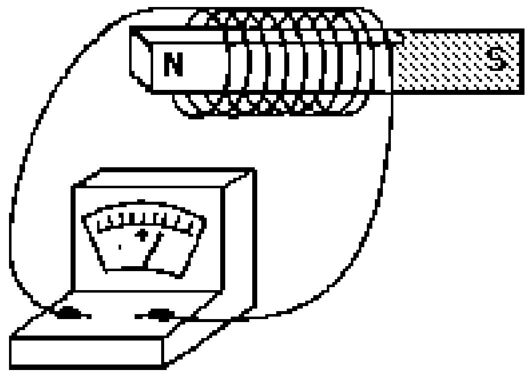


6. Reverse the attachment off the wire ends to the battery. Observe the compass and the iron filings. [The filings stay the same but the compass reversed its deflection.]
7. Would the magnetic field created around the wire be able to pick up a paper clip? [Upon trying it, the chances are very good that it will not.]
8. It occurred to Oersted that if this single loop would produce a magnetic field that looping the wire more times should produce a stronger field.
   a. Loop some wire around a pencil. Make about thirty loops. Attach the ends of the wire to the dry cell battery. Try to pick a paper clip. [This should work better.]
   b. Provide a nail long enough that it will fit in the coil and extend beyond it on either end by 1 cm. Have them try again to pick up a paper clip. [This time it will pick up a number of paper clips.]
   c. Challenge the students to a contest to build an electromagnet that can pick up more paper clips than anyone else in the classroom. Provide for them extra batteries, wire, different things (aluminum rods, paper rods, wood, plastic, crayons, chalk, glass, etc.) that they can put into the coil to take the place of the nail. Give them time to experiment before you have your contest.
   d. The winning electromagnet will probably optimize a number of factors; using more than one battery will help, the more turns in the coil will help, an iron core will help, and the often overlooked factor is that both ends of the core will pick up paper clips. Sometimes students only try to use one end.

B. Electromagnetic Induction
   1. As we saw in the first section of this lesson, when a conductor cuts the magnetic lines of force, electrons flow. As we saw in #8 above looping the wire seemed to improve the field; would using a coil and magnet produce a

greater amount of electron flow?

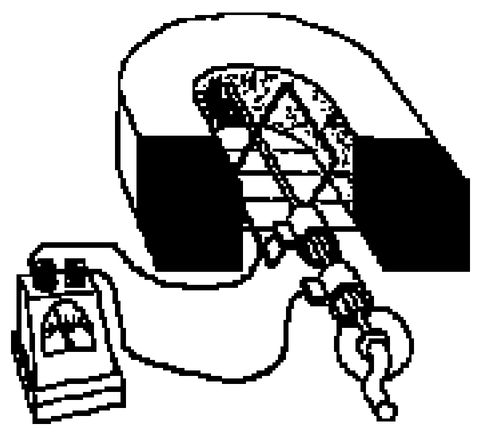
2. In place of the single loop used in A2 of the first section use a coil of wire to cut the lines of force between the poles of the horseshoe magnet. Did you see greater deflection in the galvanometer? [Yes]
3. Wrap about 4 m of insulated copper wire around a cardboard tube from a roll of paper towels. Attach the ends to a galvanometer
4. Insert a bar magnet into the cardboard tube. Move it back and forth. At first slowly, then rapidly. [Slow movement will not produce much deflection. Rapid movement produces a larger deflection. Moving in produces deflection in one direction; moving out produces deflection in the other direction.]



5. Hold the magnet still an rapidly move the coil back and forth. Was there any difference in the galvanometer readings when the tube was moving and when the magnet was moving? [No]
6. The process by which a current is produced by the relative motion of a conductor in a magnetic field is called **electromagnetic induction**.

C. Generator

1. An important application of electromagnetic induction is the operation of a generator. The movement of either the conductor or the magnet in B4 and B5 above required kinetic energy. A system that uses kinetic energy to produce electrical energy is called a **generator**.



2. In a simple hand crank generator the magnet is fixed and the coil of wire moves. Because the coil rotates, the direction of the magnetic field changes in relation to the coil. This changing direction of the magnetic field causes the current that flows in the coil to change direction as well. Thus, the current produced is alternating current.
3. Investigate a bicycle generator that operates the light. A knob on the

generator is moved so that it touches the wheel. As you pedal the bike, the moving wheel provides the kinetic energy which turns the knob which turns a shaft inside the generator. The shaft rotates a coil of wire through the magnetic lines of force of a stationary magnet. This causes current to flow which lights the headlight.

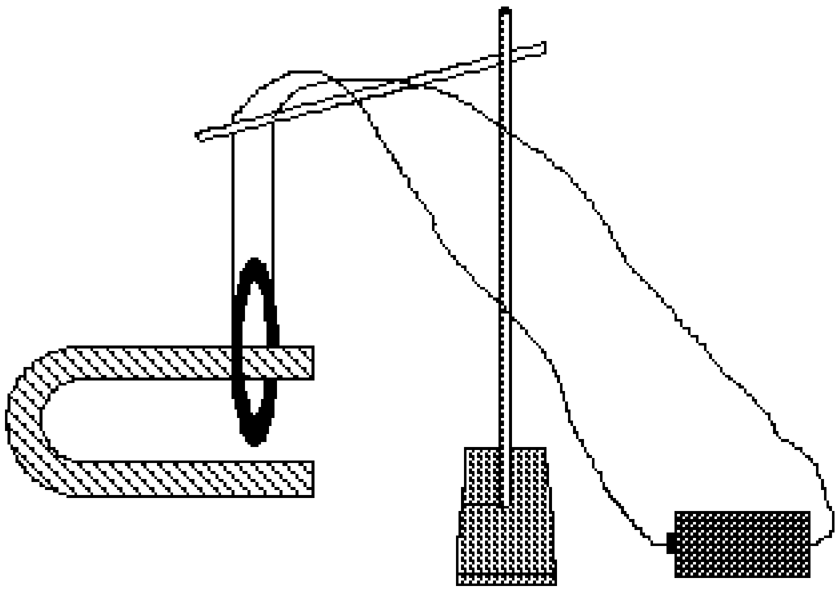
D. Motor
1. The opposite of a generator is a motor. Here, electrical energy is converted to kinetic energy. Both the generator and the motor are examples of electromagnetic induction.
2. A motor consists of an electromagnet that rotates on an axle. It rotates continuously between the two poles of a fixed permanent magnet.
3. The continuous switching of the current causes the electromagnet to be continuously repelled by the fixed magnet. It spins around and around. This kinetic energy (energy of motion) which, through electromagnetic induction, can be used to do work.

CONCEPT EXTENSION

A. Jump Rope Generator
1. How could you use an extension cord to produce electricity? The obvious answer is to plug it into the wall outlet. But this challenge is a little more difficult than that.
2. Challenge: Use only a 50 ft extension cord hooked to a galvanometer and produce electron flow.
3. After students puzzle over this for a little while suggest to them that if magnetic force lines are cut with a conductor electrons should flow. Remind them that the largest magnet in the world **is** the entire planet. Remind them that there are magnetic lines of force going around the world from pole to pole.
4. If no one has still come up with an idea, suggest to them to use the extension cord as a jump rope. As they twirl the cord they will be cutting the magnetic lines of force around the earth.
5. Details that must be attended to are:
   a. The cord must make a loop with both ends hooked to the galvanometer. Do this by attaching an alligator clip to the ground prong of the cord and via a short piece of copper wire to one terminal of the galvanometer.
   b. Jam another alligator clip into the ground receptacle on the other end of the extension cord, and attach this, via a short piece of copper wire, to the other terminal of the galvanometer.
   c. Align the extension cord in the east/west direction. Why? [When the cord is turned we want it to perpendicularly cut the lines of force that are going north/south.]
   d. Leave both ends of the extension cord on the ground and pick up the middle half and twirl it like a jump rope (you will need two twirlers.)
   e. What effect does the rotational speed of the cord have on the deflection of the galvanometer? [The faster the turning the greater the deflection of the galvanometer.]

B. Building a Primitive Motor
1. Wrap 4 m of lacquered wire around a paper towel roll to make a coil. It should have at least 30 turns. Wrap some masking tape around the coil so it doesn't fall apart. Leave 40 cm of uncoiled wire at each end.
2. Attach a horizontal rod to a ring stand. From the rod wrap the two lengths of wire from the coil so that the coil hangs 20 cm below the rod. Leave 10 cm of wire free at each end. Tape the wires to the rod.
3. With books, or bricks mount a horseshoe magnet parallel to the table so that the north pole of the magnet sticks out. Adjust the height of the magnet so that the coil hangs freely around the magnet but does not touch it.
4. Attach one of the free wires to one end of a D cell battery and briefly touch

the other wire to the other terminal of the battery. Notice what happens to the coil. [It moves in one direction.]



5. Reverse the ends of the battery that the wires are attached to. Notice what happens to the coil this time. [It moves in the opposite direction.]
6. Notice that we had to manually reverse the current through the coil. If alternating current was used as it is in a motor motion can be sustained.