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Wardha Road, Nagpur - 441108
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Approved by AICTE, New Delhi, Govt. of Maharashtra
(An Autonomous Institution Affiliated to RTM Nagpur University)

Department of Electrical Engineering

Activity Based Learning
Course: BEE2305: DC Machines & Transformer

Activity: 2– *Investigates motors and electromagnets as they construct their own simple electric motors using batteries, magnets, paperclips and wire.*

<table>
<tr><th>Sr. No.</th><th>Activity</th><th>Level</th></tr>
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Motors are used in an unlimited number of everyday devices designed by engineers. Engineers must fully understand and apply the connection between electricity and magnetism as they design and build motors, or design better and more efficient motors.

Learning Objectives
After this activity, students should be able to:

- **Create a simple motor.**
- **Describe how a motor uses an electromagnet and magnetic forces to work.**
- **Explain that motors are designed by engineers for use in various applications.**

List of Materials Require
Each group needs:

- **1 D-cell battery**
- **1 wide rubber band**
- **2 large paperclips (metal, with no coating)**
- **1 rectangular-shaped ceramic magnet (available large hardware stores such as Home Depot)**
- **43.5 in (111 cm) medium-gauge magnet wire; magnet wire is copper wire insulated with a polymer-based film, or red enamel, not plastic; available at large hardware or electronics stores such as Radio Shack**

For the entire class to share:

- **fine sandpaper**
- **needle-nose pliers or wire cutters**
- **(optional) a few compasses**
- **thread**
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Introduction/Motivation:-

Today we are going to learn a little bit about how motors work. Engineers design motors for many different uses. Motors take electrical energy, and convert it into mechanical or moving energy. Basically, motors take the electrical energy from an electricity source, such as an outlet or battery, and change that energy into something that spins, moves or does some sort of work. We interact with all sorts of motors every day. Can anyone think of some different items that have motors?

Have you ever felt the force pushing or pulling between two magnets? What happens when you put two magnets next to each other? Sometimes they stick together quickly and sometimes they push each other away. Sometimes, the magnets actually move around and then stick together. When two magnets pull together, it is because one magnet wants to align its south pole (S) with the north pole (N) of another magnet. Engineers use this magnetic force to get motors to work. Do you knows the difference between an electromagnet and a permanent magnet? Well, one difference is that the magnetic field of an electromagnet can be turned on and off by turning on or off the source of electricity to the coiled wire. Many of the magnets used in machines are actually electromagnets rather than permanent magnets. However, even though we call them "permanent," permanent magnets are not really permanent either. They can be de-magnetized by hitting them with a hammer or heating them up.

The motor that we are going to build today has three parts: a permanent magnet, a coil of wire and a battery. Something that is really important to remember is that when electricity moves through a wire, it turns the wire into an electromagnet. So, our wire coil is going to eventually act like another magnet (when we run current from the battery through it). Our simple motor will really have two magnets, and they are going to work together to create movement by pushing and pulling on each other. Building motors can be kind of tricky, and engineers must learn a lot about magnetism and electricity to get them to work. Let's get started!

Student Instructions Handout

Part 1: Making the Motor

1. Start about 1.5 in (38 mm) from the end of the wire and wrap it seven times around the short side of a rectangular magnet. Gently slide out the magnet, careful to not alter the rectangular shape of the wire. Leaving a 1.5 in (38 mm) tail opposite the original starting point, cut the wire with wire cutters or needle-nose pliers. Carefully wrap each of the two tails around the coil (closest to that end) so that the coil is securely bound together, and the two tails extend perpendicular to the coil. Your coil should look similar to Figure 1. Note: Be sure that the tails are opposite each other on the coil.

Figure 1. Magnet wire coil.

2. On one tail, use sandpaper to remove the insulation completely from the end of the tail up to ¼ in (6 mm) from the point at which the tail meets the coil. This tail should look like the left tail in the wire cross section in Figure 2. On the other tail - again leaving a ¼ in (6 mm) section of wire at the point of connection with the coil - lay the coil flat and carefully sand off the insulation from the top half of the wire. This tail should look like the right tail shown in Figure 2.

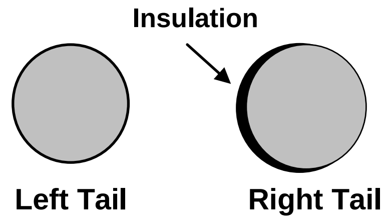

Figure 2. Cross section (or side view) of wire.

Figure 3. The bent paperclips.

3. Bend the two paper clips to look like those in Figure 3. Use needle-nosed pliers if necessary.
4. To ensure good contact at the battery terminals, sand the paper clips lightly on the surfaces that will touch the battery and the surfaces that the coil will rest on.
5. Use a rubber band to secure the large loop ends of each paper clip to the terminals of the D-cell battery. The battery, rubber band and paper clips device should look like Figure 4.

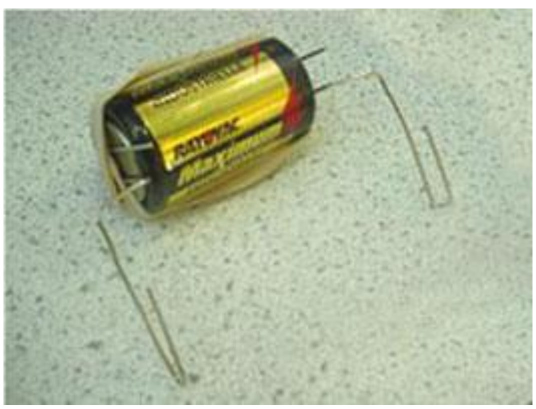

Figure 4. Use a rubber band to secure the paperclips to the battery.

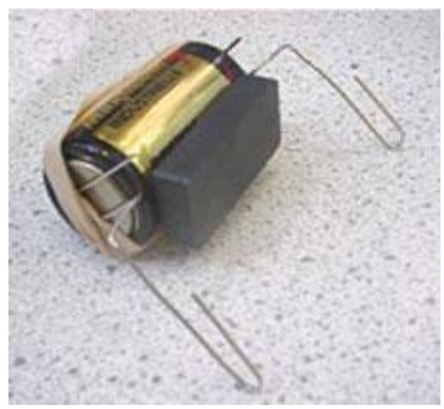

Figure 5. Battery end view, with ceramic magnet in place.

6. Place a ceramic magnet on the side of the battery (it will "stick" to the battery) as shown in Figures 5.
7. Place the coiled wire with tails into the small loops formed by the unattached ends of the paper clips ("cradles"). Your motor should look like the one in Figure 6.

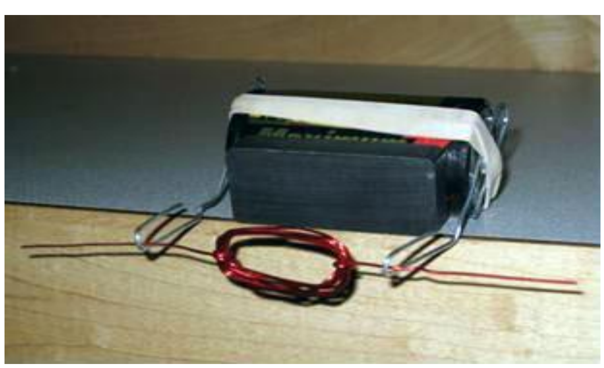

Figure 6. The complete motor setup.

8. Turn the coil slowly by hand (only touch the insulated part of the wire) and observe the magnetic attraction and repulsion between the electromagnet and the ceramic magnet.
9. (Optional) Remove the magnet from the battery. Use a compass to determine the orientation of the magnetic field of the coil. Remove the coil and replace it on the paper clips in the opposite direction. Use the compass to determine the orientation of magnetic field of the coil again.

Part 2: Making the Motor Do Work

1. Position the motor on the edge of a table or countertop (see Figure 6).
2. Bend the end of the wire that has the insulation completely removed into a very small, tight loop.
3. Tie one end of a one-foot (.3 m) long piece of thread around this loop. Tie the other end around a small paper clip.
4. Give the coil a little push to get it to start winding up the string. Once the extra loop and string are added, it may throw the motor off balance. Getting the motor to wrap the string correctly takes a significant bit of tweaking, but it will work. Use your finger as a guide.
5. Once the motor picks up one paper clip, unwind it and try connecting a second paper clip to the first. Keep adding paper clips and trying again until the motor is no longer able to lift the load. We were able to lift 16 paper clips with just this motor, so it *is* possible!

Usefull Links

https://www.youtube.com/watch?v=KsxMXVPicv0

Rubrics for Activity 2: *Investigates motors and electromagnets as they construct their own simple electric motors using batteries, magnets, paperclips and wire.*

Particulars	Poor	Good	Very Good	Satisfactory	Excellent	Total marks (Max. marks)
Marks	0 marks	0.5 mark	1 mark	1.5 mark	2 marks	2 marks
Knowledge of terms related to Activity	student don't have knowledge of all terms used in activity	student have knowledge of 1 term used in activity	student have knowledge of 2 terms used in activity	student have knowledge of 3-4 terms used in activity	student have knowledge of all terms used in activity	2 marks
Knowledge of instruments/ devices related to Activity	Students don't know about any instrument/device used in activity	Students know about only 1 instrument/device used in activity	Students know about only 2 instruments/devices used in activity	Students know about only 3 or 4 instruments/devices used in activity	Students know about all instruments/devices used in activity	2 marks
Ability to form/ construct Parts as per requirement	Not able to form/ construct Parts as per requirement	Able to form/ construct Parts as per requirement with only 1 right Parts	Able to form/ construct Parts as per requirement with only 2 right Parts	Able to form/ construct Parts as per requirement with maximum right parts	Able to form/ construct Parts as per requirement with all right connections	2 marks
Ability to make connections of required Activity	Don't able **to make connections of required Activity**	Able to make connections of required Activity with any 1 connection of model	Able to make connections of required Activity with any 2 connection of model	Able to make connection of model with any 3 connections connection of model	Able to make connection of model all the connection of model	2 marks
Accuracy of complete activity	Degree of accuracy is poor in all respect	Degree of accuracy is very low in all respect	Degree of accuracy is low in all respect	Degree of accuracy is moderate in all respect	Degree of accuracy is high in all respect	2 marks
Total marks						**10 marks**

Activity Based Learning
Course: BEE2305: DC Machines & Transformer

Activity: 1 – *Student teams investigate the properties of electromagnets*

They create their own small electromagnets and experiment with ways to change their strength to pick up more paperclips. Students learn about ways that engineers use electromagnets in everyday applications.

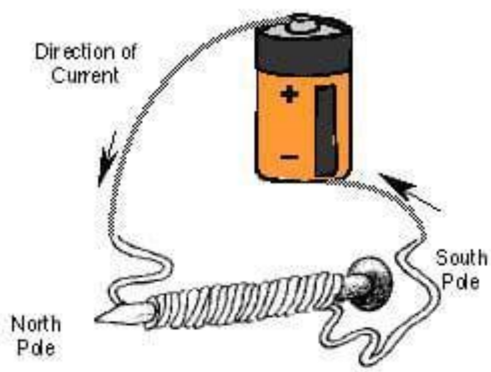

Figure 1. A basic electromagnet.

Engineering Connection

Engineers design electromagnets, which are a basic part of motors. Electromagnetic motors are a big part of everyday life, as well as industries and factories. We may not even realize that we interact with electromagnets on a daily basis as we use a wide variety of motors to make our lives easier. Common devices that use electromagnetic motors are: refrigerators, clothes dryers, washing machines, dishwashers, vacuum cleaners, sewing machines, garbage disposals, doorbells, computers, computer printers, clocks, fans, car starters, windshield wiper motors, electric toothbrushes, electric razors, can openers, speakers, music or tape players, etc.

Learning Objectives

After this activity, students should be able to:

- *Relate that electric current creates a magnetic field.*
- *Describe how an electromagnet is made.*
- *Investigate ways to change the strength of an electromagnet.*
- *List several items that engineers have designed using electromagnets.*

Each group needs:

- nail, 3-inch (7.6 cm) or longer (made of zinc, iron or steel, but not aluminum)
- 2 feet (.6 m) insulated copper wire (at least AWG 22 or higher)
- D-cell battery
- several metal paperclips, tacks or pins
- wide rubber band

For each electromagnetic field station:

- cardboard toilet paper tube
- insulated copper wire (at least AWG 22 or higher), several feet (1 m)
- cardboard (~ 5 x 5 inches or 13 x 13 cm)
- clothespins or clamps (optional)
- masking tape
- rubber band
- 2-3 D-cell batteries
- 9-V (volt) battery
- several metal paperclips, tacks and/or pins
- extra batteries, if available: 6-V, 12-V, lantern batteries
- (optional) electrical tape
- 2 small orienteering compasses

For the entire class to share:

- wire cutters
- wire strippers

Pre-Req Knowledge

- Some knowledge of magnetic forces (poles, attraction forces).

Procedure

Before the Activity

- Gather materials and make copies of the Building an Electromagnet Worksheet.
- Set up enough Electromagnetic Field Stations to accommodate teams of two students each.
- As an alternative, conduct both parts of the activity as teacher-led class demonstrations.

Figure 2. Setup for an Electromagnetic Field Station.

1) Prepare for Electromagnetic Field Stations: Wrap wire around a cardboard toilet paper tube 12-15 times to make a wire loop. Leave two long tails of wire hanging from the coil. Poke four holes in the cardboard. Weave the wire ends through the cardboard holes so that the card board tube and coil are attached to the cardboard (see Figure 2). Use clothespins, clamps or tape to secure the cardboard to a table or desk. Using masking tape or rubber band, connect one end of the coil wire to any battery, leaving the other end of the wire not connected to the battery. Place some pins, paperclips or tacks at the station. Also, place any other available extra batteries (6V, 12V, etc.) and two, small orienteering compasses at this station.
2) Prepare for Building an Electromagnet: For this portion of the activity, either set up the materials at a station, or give them to pairs of students to work on at their desks.
3) Set aside a few extra batteries for students to test their own electromagnets. These might include the 9-V batteries. You can make a 3-V battery setup by connecting 2 D-cells in series or a 4.5-V battery setup by connecting 3 D-cells in series.
4) Cut one 2-ft (.6 m) piece of wire for each team. Using wire strippers, remove about ½ inch (1.3 cm) of insulation from both ends of each piece of wire.

With the Students: Electromagnetic Field Stations

- Divide the class into pairs of students. Hand out one worksheet per team.
- Working from the pre-activity setup (see Figure 2), in which one end of the coiled wire is attached to one end of the battery, have students connect the other end of the wire to the other end of the battery using tape or rubber band.
- To locate the magnetic field of the electromagnet, direct students to move the compass in a circle around the electromagnet, paying attention to the direction that the compass points (see Figure 3). Direct students to draw the battery, coil and magnetic field on their worksheets. Use arrows to show the magnetic field. Label the positive and negative ends of the battery and the poles of the magnetic field. What happens if you dangle a paperclip from another paperclip near the coil (see Figure 3)? (Answer: The dangling paperclip moves, changes direction and/or wobbles.)

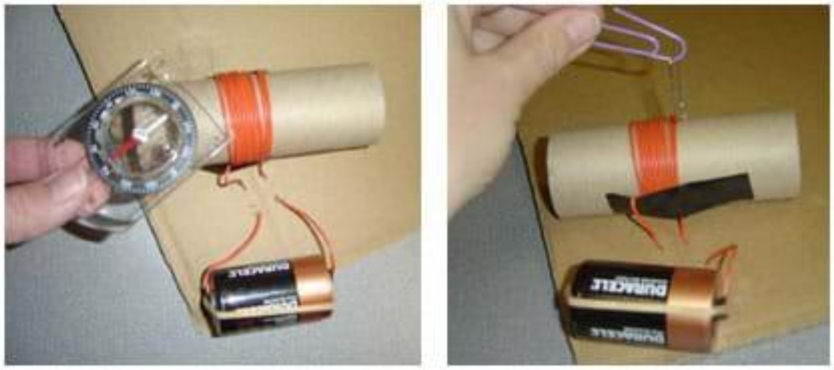

Figure 3. Experimenting with the magnetic field of the electromagnet.

- Next, reverse the connection of the electromagnet by changing both ends of the wire to the opposite ends of the battery. (When the direction of current is reversed in either a coil or electromagnet, the magnetic poles reverse—the north pole becomes the south pole, and the south pole becomes the north pole.) Use the compass to check the direction of the magnetic field. Make a second drawing. Dangle the paperclip near the coil again. What happens? (Answer: Again, the dangling paperclip moves, changes direction and/or wobbles.)
- Remove at least one end of the wire from the battery to conserve battery power.
- If time permits, use different batteries and observe any changes. A higher voltage translates to a greater current, and with more current, the electromagnet becomes stronger.

With the Students: Building an Electromagnet

1. Make sure each student pair has the following materials: 1 nail, 2 feet (.6 m) of insulated wire, 1 D-cell battery, several paperclips (or tacks or pins) and a rubber band.
2. Wrap the wire around a nail at least 20 times (see Figure 4). Ensure students wrap their nails tightly, leaving no gaps between the wires and not overlapping the wraps.
3. Give the students several minutes to see if they can create an electromagnet on their own before giving them the rest of the instructions.
4. To continue making the electromagnet, connect the ends of the coiled wire to each end of the battery using the rubber band to hold the wires in place (see Figure 4).

Figure 4. Setup to make an electromagnet using a battery, wire and nail.

5. Test the strength of the electromagnet by seeing how many paperclips it can pick up.

6. Record the number of paperclips on the worksheet.
7. Disconnect the wire from the battery after testing the electromagnet. Can the electromagnet pick up paperclips when the current is disconnected? (Answer: No)
8. Test how varying the design of the electromagnet affects its strength. The two variables to modify are the number of coils around the nail and the current in the coiled wire by using a different size or number of batteries. To conserve the battery's power, remember to disconnect the wire from the battery after each test.
9. Complete the worksheet; making a list of ways engineers might be able to use electromagnets.
10. Conclude by holding a class discussion. Compare results among teams. Ask students the post-assessment engineering discussion questions provided in the Assessment section.

Rubrics for Activity 1: ***Student teams investigate the properties of electromagnets***

Particulars	**Poor**	**Good**	**Very Good**	**Satisfactory**	**Excellent**	**Total marks (Max. marks)**
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Total marks						**10 marks**