Drexel-SDP GK-12 ACTIVITY

Subject Area(s): Physical Science, Science & Technology

Associated Unit: Magnetism

Associated Lesson:

Activity Title: "From Wind to Current"

Grade Level: 10th-12th

Time Required: 2 hours

Group Size: 3 students per group

Expendable Cost per Group: $10

Summary
To learn about the principles of magnetism in a generator or motor students will design an experiment to determine the effects of coil design and orientation on the amount of current produced. They will specifically look at coil radius, coil depth, number of turns on the coil and also the distance between magnets.

Engineering Connection
Electrical or mechanical engineers are the most likely to be involved in the design of motors for different applications. Currently there is a growing interest in harvesting energy from wind by designing efficient wind turbines. This involves understanding the principles of magnetism and electricity for the design of a wind turbine.

Keywords
Magnetism, wind turbine, generator, alternator

Educational Standards
- Math: 2.5.8.B
- Science: 3.4.10.C
- Science: 3.6.10.C and 3.6.12.C
- Science: 3.8.10.A

Pre-Requisite Knowledge
Students should know the basics of electricity and magnetism.

Learning Objectives
After this lesson, students will be able to:
1. Design a generator using alternating current
2. Explain the relationship between inductance and coil parameters (radius, depth and number of turns).
3. Use a voltmeter to measure the current or voltage of a circuit.
4. Describe the relationship between magnets and electricity.

Materials List
Each group needs:
1. 2 ceramic magnets
2. 2 paper clips
3. Digital voltmeter
4. Insulated copper wire
5. 50 mL glass beaker
6. Ruler
7. 2 clamps
8. 2 ring stands
9. Scissors

Introduction / Motivation
In our world it has become a priority to design new ways to create energy from the natural world. One way is to harvest the energy in wind into electrical energy using a wind turbine. One of the most important components of the wind turbine is the generator. This is the device that actually converts the turns of the blades into current using magnets and a copper coil.
As all of you know magnets have poles on either side that either attract or repel other magnetic materials due to the magnetic fields that come out of it. When a conductor crosses these magnetic fields the electrons in the conductor begin to move. If a conductor continues to cross the field then an alternating current is produced which can be used as electricity.
To make this generator really efficient then we most optimize some of the parameters in order to get the most current.

Vocabulary / Definitions

Word	Definition
Generator	Also known as a motor is a device that can convert mechanical energy into electrical energy.
Wind Turbine	A machine that rotates by the wind and converts the mechanical energy into electrical energy.
Magnetism	Force exerted by the magnetic field from a magnet
Inductance	The ratio of the magnetic flux to the current
Magnetic flux	A measure of the strength of the magnetic field around a magnet
Alternator	A type of generator that converts mechanical energy to electrical energy in the form of alternating current.

Procedure
Background
When designing a wind turbine there are a few parameters that can be optimized to achieve a greater output. One of them is blade design and the other is the generator. For this lesson we are going to focus on the generator for the case when the magnetic coil crosses the magnetic field as it rotates (Figure 1).
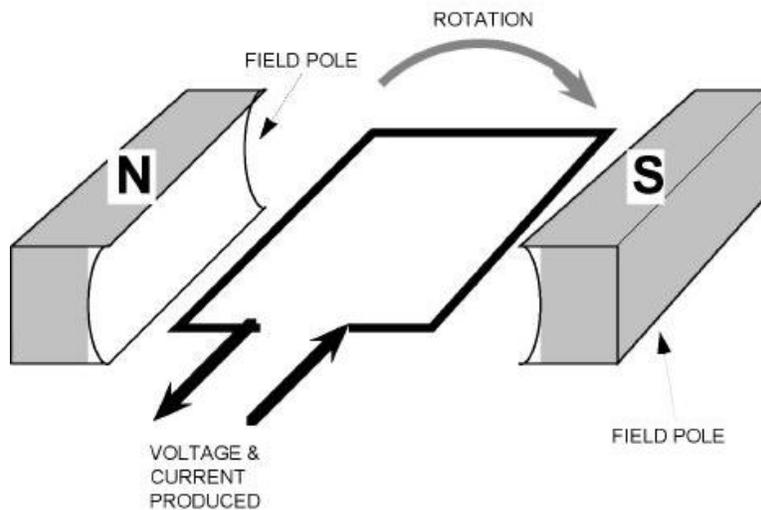

Figure 1: Schematic of a generator design where the magnetic coil rotates through the magnetic field created by two magnets.

Inductance is the ratio of magnetic flux to current so to achieve a high current the inductance created by the coil must be low. Inductance of a coil (L) depends on the radius of the coil, the number of turns and the depth of the coil (Figure 2).

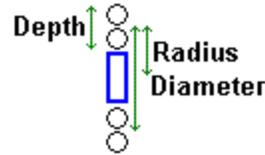$$L = \frac{Radius^2 \times Turns^2}{8\,Radius + 11\,Depth}$$

Depth, Radius, Diameter

Figure 2: Formula for the inductance of a coil and the schematic depicting the variables.

With the Students

1. First determine at what distance the magnets begin to attract or repel each other. Make sure you record this number.
2. Take the copper wire and coil it around the glass beaker until you get at least 100 turns. Leave at least 5 inches of wire on each side of the coil.
3. Measure the diameter of your beaker. This will be the diameter of your coil which will be important for your calculations later.
4. Remove the coil from the beaker and make it into a compact circle. Use the extended wire to tightly loop around the coils a few times to keep it from expanding (Figure 3).
5. Using the scissors completely strip two inches of insulation from both ends of the coiled wire. You will know it is removed when the red color is gone and only the shiny copper is visible.
6. Completely unfold two paperclips and make a small loop one of the ends of the paperclip. The other end should be straight.
7. Set up the ring stands and clamp the paperclip straight ends so they hang downward.
8. Insert both ends of the coiled wire into the paperclip loops so the coil is now hanging in the air.
9. Place one magnet on top of a textbook and place the second magnet directly across the second magnet on top of another book at a distance slightly larger than the distance you found in step 1. The coil should now be sitting in between both magnets.
10. Connect the leads of the voltmeter to each paperclip and set the voltmeter to record microvolts.
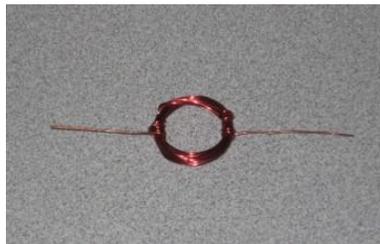11. Spin the coil and the record the voltage produced.

Figure 3: Wire wrapped into a coil. Loops on both sides of the coil keep it from expanding.

In groups:
Divide the class into 4 groups and each group will record the voltage (or current) for a different independent variable.
- Group 1 will change the number of turns in the coil.
- Group 2 will change the radius of the coil.
- Group 3 will change the depth of the coils.
- Group 4 will change the distance of the magnets.

Safety Concerns
If the magnets are strong students should be careful not to bring them to close together or they could hurt their fingers.

Troubleshooting
If the voltmeter does not detect a reading then check the wire stripping. Make sure the insulation is completely removed at the area where the wire makes contact with the paperclip loops.

Assessment
Pre-Activity Assessment
Title: Class discussion
Students will get a chance to share their hypothesis on what they think will happen to the voltage as they change the size, the number of turns and the depth of the coil.

Activity Embedded Assessment
Title: Group activity
With the students divided into 4 groups have them graph the relationship between voltage and their particular independent variable (Radius, depth, turns and distance between magnets. Each group should change their variable at least 3 times. They should also calculate the inductance after each variable change.

Post-Activity Assessment
Title: Class Presentation
After the activity is completed each group will have to present in front of the classroom their particular experiment. Each group should be prepared how their variable affects the voltage output.

Reference

Owner
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