Activity 4

**AC & DC Currents**

**GOALS**
In this activity you will:
- Describe the induced voltage and current when a coil is rotated in a magnetic field.
- Compare AC and DC generators in terms of commutators and outputs.
- Sketch sinusoidal output wave forms.

**What Do You Think?**
In the last activity, you used human energy to produce motion to generate electricity.

- **What other kinds of energy can generate electricity?**

Write your answer to this question in your *Active Physics* log. Be prepared to discuss your ideas with your small group and other members of your class.

**For You To Do**

**AC Generator**

1. Your teacher will explain and demonstrate a hand-operated, alternating current (AC) generator. During the demonstration, make the observations necessary to gain the information needed to answer these questions:

   a) When the AC generator is used to light a bulb, describe the brightness of the bulb when the generator is cranked slowly, and then rapidly. Write your observations in your log.

   b) When the AC generator is connected to a galvanometer, describe the action of the galvanometer needle when the generator is cranked slowly, and then rapidly.
2. It is easier to understand the creation of a current if you think of a set of invisible threads to signify the magnetic field of the permanent magnets. The very thin threads fill the space and connect the north pole of one magnet with the south pole of the other magnet. If the wire of the generator is imagined to be a very thin, sharp knife, the question you must ask is whether the knife (the wire) can “cut” the threads (the magnetic field lines). If the wire moves in such a way that it can cut the field lines, then a current is generated. If the wire moves in such a way that it does not cut the field lines, then no current is generated.

a) Look at the diagrams of the magnetic fields shown. In which case, I, II, or III will a current be generated?

3. The following diagram shows the position of the rotating coil of an AC generator at instants separated by one-fourth of a rotation of the coil. Build a small model of the rectangular coil so that you can move the model to help you understand the drawings. The coil model can be constructed by carefully bending a coat hanger into the shape of the rectangular coil. Rest the coil between two pieces of paper—label the left paper N for the north pole of a magnet; label the right paper S for the south pole of a magnet.
4. For the purpose of analyzing the rotating coil figure, the four sides of the rectangular coil of the AC generator will be referred to as sides AB, BC, CD, and DA. Side DA is “broken” to allow extension of the coil to the rings. The “brushes,” labeled 1 and 2, make sliding contact with the rings to provide a path for the induced current to travel to an external circuit (not shown) connected to the brushes. The magnetic field has a left-to-right direction (from the north pole to the south pole) in the space between the magnets in the rotating coil figure. It is assumed that the coil has a constant speed of rotation.

\( a \) When the generator coil is in position I shown in the rotating coil, is a current being generated? A current is produced if the wire cuts the magnetic field lines. Record your answer and the reason for your answer in your log.

\( b \) Use a graph similar to the one shown below. Plot a point at the origin of the graph, indicating the amount of induced current is zero at the instant corresponding to the beginning of one rotation of the coil.

\( c \) One-fourth turn later, at the instant when the rotating coil is in position II, is a current being generated? Record your answer and the reason for your answer in your log.

\( d \) On your graph, plot a point directly above the \( \frac{1}{4} \)-turn mark at a height equal to the top of the vertical axis to represent maximum current flow in one direction.

The current induced by an AC generator during one rotation of the generator coil

<table>
<thead>
<tr>
<th>Current, one direction</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>No current</td>
<td>1/4 1/2 3/4 1</td>
</tr>
<tr>
<td>Current, opposite</td>
<td></td>
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</table>
e) One-half turn into the rotation of the coil, at the instant shown in the rotating coil position III, the current again is zero because all sides of the coil are moving parallel to the magnetic field. Plot a point at the $\frac{1}{2}$ mark on the horizontal axis to show that no current is being induced at that instant.

f) At the instant at which $\frac{3}{4}$ of the rotation of the coil has been completed, shown by the rotating coil in position IV, the induced current again is maximum because coil sides AB and CD again are moving across the magnetic field at maximum rate. However, this is not exactly the same situation as shown in the rotating coil position II; it is a different situation in one important way: the direction of the induced current has reversed. Follow the directions of the arrows which represent the direction of the current flow in the coil to notice that, at this instant, the current would flow to an external circuit out of brush 2 and would return through brush 1. On your graph, plot a point below the $\frac{3}{4}$-turn mark at a distance as far below the horizontal axis as the bottom end of the vertical axis. This point will represent maximum current in the opposite, or “alternate,” direction of the current shown earlier at $\frac{1}{4}$-turn.

g) The rotating coil in position I is used again to show the instant at which one full rotation of the generator coil has been completed. Again, all sides of the coil are moving parallel to the magnetic field, and no current is being induced. Plot a point on the horizontal axis at the 1-turn mark to show that the current at this instant is zero.

5. You have plotted only 5 points to represent the current induced during one complete cycle of an AC generator.

a) Where would the points that would represent the amount of induced current at each instant during one complete rotation of the generator coil be plotted?

b) What is the overall shape of the graph? Should the graph be smooth, or have sharp edges? Sketch it to connect the points plotted on your graph.

c) What would the graph look like for additional rotations of the generator coil, if the same speed and resistance in the external circuit were maintained?
Toys for Understanding

**DC Generator**

6. Your teacher will explain and demonstrate a hand-operated, direct current (DC) generator. During the demonstration, make the observations needed to answer these questions:

   a) When the DC generator is used to light a bulb, describe the brightness of the bulb when the generator is cranked slowly, and rapidly. Write your observations in your log.

   b) When the DC generator is connected to a galvanometer, describe the action of the galvanometer needle when the generator is cranked slowly, and rapidly.

7. The diagram shows important parts of a DC generator. As in Step 3, build a model of the generator to help you analyze how it works.

8. Use a graph similar to the one shown below. Complete the graph using the same pattern of analysis applied to the AC generator.

   a) At the instant shown in the DC generator diagram, the induced current is maximum. The instant corresponds to the rotating coil II. Plot a point on the graph directly above the $\frac{1}{4}$-turn mark at a height equal to the top of the vertical axis to represent maximum current flow at that instant.

   b) At the instant $\frac{1}{4}$-turn earlier than the instant shown in the DC generator figure, corresponding to the zero mark of rotation, the current would have been zero because all sides of the coil would have been moving parallel to the direction of the magnetic field. Therefore, plot a point at the origin of the graph.

   c) Similarly, the induced current again would be zero at the instant $\frac{1}{4}$-turn later than the instant shown in the DC generator figure; therefore, plot a point on the horizontal axis at the $\frac{1}{2}$-turn mark.

<table>
<thead>
<tr>
<th>The current induced by a DC generator during one rotation of the generator coil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
</tr>
<tr>
<td>No current</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coil rotation, fraction of turn</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{4}$</td>
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9. Notice the arrangement used to transfer current from the generator to the external circuit for the DC generator. It is different from the arrangement used for the AC generator. The DC generator has a “split-ring commutator” for transferring the current to the external circuit. Notice that if the coil shown in the DC generator figure were rotated \( \frac{1}{4} \)-turn in either direction, the “brush” ends that extend from the coil to make rubbing contact with each half of the split ring would reverse, or switch, the connection to the external circuit. Further, notice that the connection to the external circuit would be reversed at the same instant that the induced current in the coil reverses due to the change in direction in which the sides of the coil move through the magnetic field. The outcome is that while the current induced in the coil alternates, or changes direction each \( \frac{1}{2} \)-rotation, the current delivered to the external circuit always flows in the same direction. Current that always flows in one direction is called direct current, or DC.

a) Plot a point on the graph at a point directly above the \( \frac{3}{4} \)-turn mark at the same height as the point plotted earlier for the \( \frac{1}{4} \)-turn mark.

b) As done for the AC generator, find out how to connect the points plotted on this graph to represent the amount of current delivered always in the same direction to the external circuit during the entire cycle.

**Reflecting on the Activity and the Challenge**

It is time to begin preparing for the **Chapter Challenge**. Now that you know how a generator works, you should begin to think about toys that might generate electricity. You should also think about how you could assemble “junk” into a toy generator, or do some research on homemade generators and motors.
Physics To Go

1. What is the purpose of:
   a) An electric generator?
   b) An electric motor?

2. How does a direct current differ from an alternating current? Use graphs to illustrate your answer.

3. In an electric generator, a wire is placed in a magnetic field. Under what conditions is a current generated?

Stretching Exercises

1. What is the meaning of “hertz,” abbreviated “Hz,” often seen as a unit of measurement associated with electricity or stereo sound components such as amplifiers and speakers?

2. What does it mean to say that household electricity has a frequency of 60 Hz?

3. Have you ever heard 60 Hz AC being emitted from a fluorescent light or a transformer?

4. Look at a catalog or visit a store where sound equipment is sold, and check out the “frequency response” of speakers—what does it mean?

5. Heinrich Hertz was a 19th-century German physicist. Find out about the unit of measurement named after him, and write a brief report on what you find.