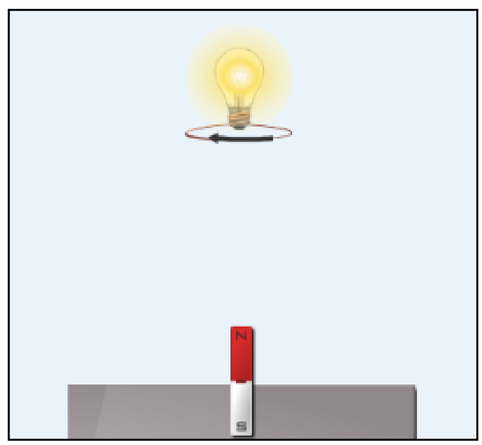
Name: ______________________________ Date: ____________________

Student Exploration: Electromagnetic Induction

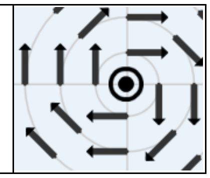
Vocabulary: current, electric field, electromagnetic induction, magnetic field, magnetic flux, right-hand rule, vector, voltage, wind generator

Prior Knowledge Question (Do this BEFORE using the Gizmo.)
A **wind generator**, such as the one shown at left, uses the power of wind to generate electricity. What do you think is happening inside the wind generator to convert the energy of the spinning blades into electricity? Make your best guess.

Gizmo Warm-up
Usually when you experiment with circuits, you use a battery or another energy source to create a current. But is it possible to generate a **current** without a battery? You can find out with the *Electromagnetic Induction* Gizmo.



In the Gizmo, you can drag the wire loop around or use the controls to move the magnet up and down. You can also rotate the wire loop. Experiment with the Gizmo to see how many different ways you can create a current in the wire loop and light the light bulb. Describe your findings below.

Activity A: **Electromagnetic fields**	Get the Gizmo ready: • Turn on **Show electric field at sensor**. • Click **Reverse** to move the magnet down and set the **Speed** to 10 cm/s.	

Introduction: When electric current runs through a wire, it induces a **magnetic field** near the wire. Similarly, **electric fields** can be created in the process of **electromagnetic induction**.

Question: How do magnets induce electric fields?

1. Observe: While the magnet is *not* moving, is there any electric field? _________________

2. Sketch: Click **Forward**, and observe the electric field display. (Note: This display shows a top view of the electric field picked up by the sensor at the top of the SIMULATION pane.) Sketch the electric field at right.

   Notice the electric field consists of an array of arrows, or **vectors**. Each vector represents the force on a positive charge located at the base of the vector.

   What do you notice? ___________________________

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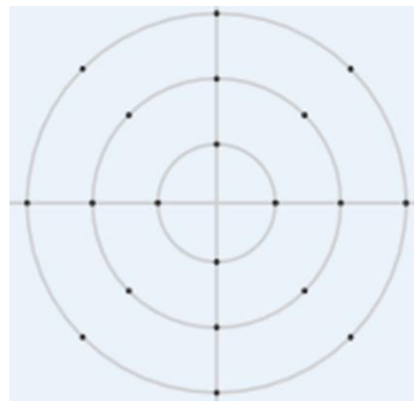

3. Experiment: Click **Reverse** and observe the electric field as the magnet moves away.

   A. How does changing the direction of the magnet affect the electric field?

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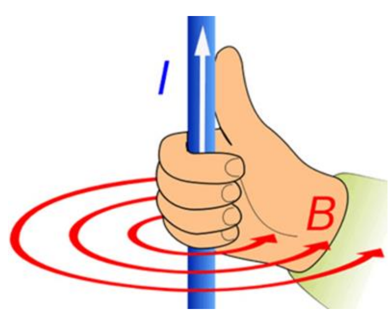
   B. Increase the **Speed** to 20 cm/s, and then click **Forward**. How does increasing the speed of the magnet affect the strength of the electric field?

   ____

4. Make a rule: If you have studied how currents induce magnetic fields, you may recall the **right-hand rule**, illustrated at right. For electric currents, the thumb represents the direction of positive charge (*I*) and the fingers represent the induced magnetic field (*B*).

   To describe the electric field induced by a moving magnet, you can use a "left-hand rule." What do the thumb and fingers of your left hand represent in this case?

   Thumb: _____________________________ Fingers: _____________________________



Activity B: **Induced currents**	<u>Get the Gizmo ready</u>: • Check that **Show electric field at sensor** is on. • Click **Reverse** to move the magnet down and set the **Speed** to 10 cm/s.	

Question: How do magnets induce electric currents?

1. <u>Observe</u>: Drag the wire loop directly above the magnet. Click **Forward** and observe the wire loop and light bulb. As the magnet is moving, click the **camera** ( ) icon to take a snapshot. Right-click the image, and click Copy Image. Paste this image into a blank document.

   A. What do you notice in the wire? ____

   B. How does the direction of the current in the loop compare to the electric field?

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   Recall that the vectors in the electric field represent the forces on *positive* charges. Currents in wires are carried by moving electrons, which are negatively charged. Therefore, the electrons move in the opposite direction as the arrow on the wire.

   C. Click **Reverse**. How does this affect the direction of the current? _______________

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2. <u>Compare</u>: Turn on **Show loop data**. The current (*I*) in the loop is measured in amperes. Click **Forward** and observe both the current and the electric field.

   A. How does the current change as the magnet approaches the loop? _____________

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   B. How does the electric field change as the magnet approaches the loop? __________

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3. <u>Compare</u>: Increase the **Speed** to 20 cm/s, and click **Reverse** to move the magnet down. Click **Forward** and observe both the current and the electric field.

   A. How does increasing the magnet's speed affect the current? ___________________

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   B. How does increasing the magnet's speed affect the electric field? _______________

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(Activity B continued on next page)

Activity B (continued from previous page)

4. Sketch: Turn off **Show loop data** and turn on **Show magnetic field**. The lines in the magnetic field connect the north and south poles of the bar magnet. A compass placed next to the magnet will align with the magnetic field lines, with the north pole of the compass pointing toward the south pole of the magnet.

   

   Sketch the magnetic field around the magnet at right.

5. Gather data: Click **Reverse** to move the magnet down to the bottom. The wire loop should be directly above the magnet, as low as you can drag it.

   A. How many magnetic field lines are currently going through the loop? _____________

   B. Click **Forward** and wait until the magnet gets to the top. How many field lines are passing through the loop now? _____________

6. Observe: The number of lines is proportional to the **magnetic flux** (Φ_M) through the loop. Magnetic flux is a measure of how powerful the magnetic force is through a given area. An electric current can only be induced if the magnetic flux is changing through the loop.

   Click **Reverse** to move the magnet to the bottom. Turn on **Show loop data** and click **Forward**. How does the magnetic flux change as the magnet rises?

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7. Draw conclusions: In general, how do the current and electric field relate to the change in magnetic flux?

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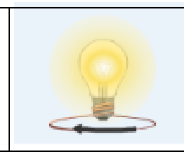
8. Challenge: Michael Faraday (1791–1867), who is generally credited as the discoverer of electromagnetic induction (in 1831), discovered the relationship between **voltage** (V), the force that creates a current in a wire, and the magnetic flux.

   Faraday's law of magnetic induction relates voltage to the change in magnetic flux ($\Delta\Phi_M$) and the time interval (Δt). Based on the observations you have made, what is Faraday's law? Check your answer with your teacher.

$$V =$$

Activity C: **Moving the loop**	Get the Gizmo ready: • Click **Forward** to move the magnet to the top. • Turn off **Show magnetic field**.	

Question: Can electric currents be induced by moving the wire loop?

1. Predict: Do you think you can induce an electric current in the wire loop by moving or rotating the loop? Explain why or why not.

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2. Observe: Check that **Show loop data** is on. Move the wire loop up, away from the magnet.

   A. Is a current produced in the wire? __________

   B. If so, in which direction is the current moving, left or right? __________

   C. Is this motion of the loop equivalent to the magnet moving up or down? __________

   D. Is the magnetic flux increasing or decreasing as you do this? __________________

3. Observe: Move the wire loop down, towards the magnet.

   A. In which direction is the current moving? __________

   B. Is this motion of the loop equivalent to the magnet moving up or down? __________

   C. Is the magnetic flux increasing or decreasing as you do this? __________________

4. Summarize: In general, what is the direction of the current if the magnetic flux is increasing? What is the direction when the magnetic flux is decreasing?

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5. Explore: Try moving the loop slowly, then fast. Observe the magnitude of the current as you do this. How does the speed of the loop affect the current?

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(Activity C continued on next page)

Activity C (continued from previous page)

6. Experiment: Drag the loop to the left edge, and then slowly move the loop horizontally to the right edge. Observe the flux as you do this.

    A. Is a current produced in the wire? ___________

    B. What do you notice about the direction of the current as the wire crosses the midpoint? ____

    C. What causes the direction of the current to change? ___________________________

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7. Experiment: Turn on **Show magnetic field**. Position the loop over the magnet. Click **Play** ( ). What do you notice? ____

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8. Explain: As the loop rotates, why is a current induced in the loop? _____________________

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9. Apply your knowledge: At the beginning of this exercise, you were asked to guess how a wind generator uses the power of wind to produce an electric current. Now you can use what you have learned to explain what is really happening. Add a sketch at right if you like.

    How does a wind generator work? ______________

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