Power Move: Manipulating Magnets to Improve Generator Output

https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p079/electricity-electronics/manipulating-magnets-to-improve-generator-output (http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p079/electricity-electronics/manipulating-magnets-to-improve-generator-output)

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Experimental Procedure

Safety Notes about Neodymium Magnets:

- *Handle magnets carefully.* Neodymium magnets (used in this science project) are strongly attracted and snap together quickly. Keep fingers and other body parts clear to avoid getting severely pinched.
- *Keep magnets away from electronics.* The strong magnetic fields of neodymium magnets can erase magnetic media like credit cards, magnetic I.D. cards, and video tapes. It can also damage electronics like TVs, VCRs, computer monitors, and other CRT displays.
- *Keep magnets away from young children and pets.* These small magnets pose a choking hazard and can cause internal damage if swallowed.
- *Avoid use around people with pacemakers.* The strong magnetic field of neodymium magnets can disrupt the operation of pacemakers and similar medical devices. Never use neodymium magnets near persons with these devices.
- *Use the magnets gently.* Neodymium magnets are more brittle than other types of magnets and can crack or chip. Do not try to machine (cut) them. To reduce the chance of chipping, avoid slamming them together. Eye protection should be worn if you are snapping them together at high speeds, as small shards may be launched at high speeds. Do not burn them; burning will create toxic fumes.
- *Be patient when separating the magnets.* If you need to separate neodymium magnets, they can usually be separated by hand, one at a time, by sliding the end magnet off the stack. If you cannot separate them this way, try using the edge of a table or a countertop. Place the magnets on a tabletop with one of the magnets hanging over the edge. Then, using your body weight, hold the stack of magnets on the table and push down with the palm of your hand on the magnet hanging over the edge. With a little work and practice, you should be able to slide the magnets apart. Just be careful that they do not snap back together, pinching you, once you have separated them.
- *Wear eye protection.* Neodymium magnets are brittle and may crack or shatter if they slam together, possibly launching magnet fragments at high speeds.

In this electronics science project, you will need to wind an iron core, which will have six layers of wire, with 200–250 wraps of wire per layer. This is a lot of winding! Be patient, take your time, and we highly recommend creating a tool to help you wind *neatly* and efficiently (further explained later). Wiring the cores neatly into coils is essential for your generator to work well.

Build a Wire Spool Dispenser

We strongly suggest—though it is not essential—that you first build a wire spool dispenser. It will be helpful for when you wind the iron cores, as explained in the next section. Figure 4 shows two examples of homemade tools built to dispense magnet wire. You can choose to temporarily use some of the materials provided in the kit (see the figure on the left) or build a simplified version from household materials, such as a cardboard box, a pencil, masking tape, and a drinking straw (figure on the right).

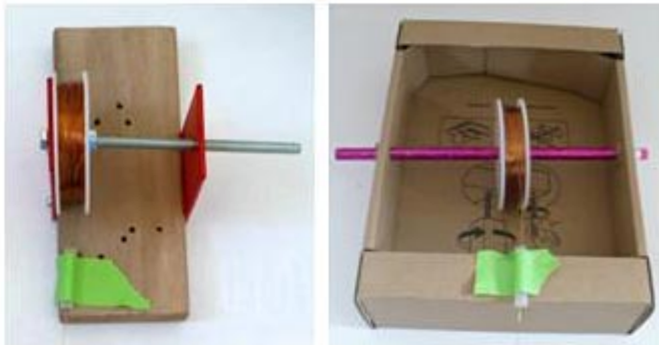

Figure 4. Pictures of wire dispensers made from materials included in the kit (left) or from household materials (right).

This video shows an alternative way to wind coils. Be sure to use the drill on the slowest setting, ask for help to hold the drill, and concentrate on winding the coils carefully one next to the other.

https://www.youtube.com/watch?v=-Xl63aqWaTk (https://www.youtube.com/watch?v=-Xl63aqWaTk)

If you have one available, you can use a power drill to speed up the coil-winding process. You should ask an adult for help with this step.

Wind the Coils

It is very difficult to wind the iron core neatly without the help of a tool. You can transform the box in which your kit came into a coil winder with a hand crank. This will not only help you coil the wire neatly, but it will also drastically increase your efficiency.

Let Figure 5 be your guide throughout the instructions.

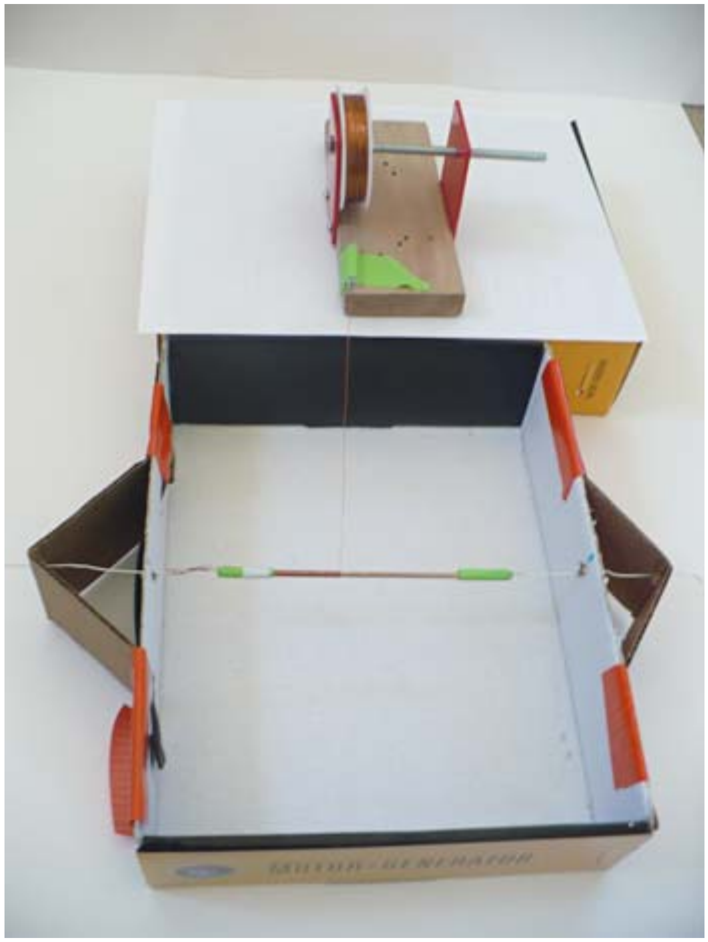

Figure 5. A coil winder like the one depicted here helps wind an iron core neatly with magnet wire.

1. Put the box your kit comes in (or a cardboard box of approximately 7–8 inches wide) in front of you, as shown in Figure 6.
2. Poke holes in the middle of *both* of the long side panels of the box, approximately 1/2 inch (1.3 cm) from the top edge of the box.

Figure 6. Box with hole in the middle of the long side of the box. You should do this to both long sides.

3. Take two pieces of corrugated cardboard, both approximately 14 inches (36 cm) long and 2 inches (5 cm) wide. Corrugations should run parallel to the short side, so the board folds easily along this side.
4. Make a fold in the middle, then unfold it.
5. Fold each half in half, but in the opposite direction from which you made your first fold. When you're finished, you have four equal rectangles and the folds create a V shape with flaps, as shown in Figure 7.
6. Poke a hole about 1/2 inch (1.3 cm) below the edge in the middle fold.

Figure 7. Pieces of corrugated cardboard that are folded in a V shape with flaps will help support the axle of the tool to help wind the iron cores.

7. Use masking tape to attach the flaps of the V shapes to the sides of the box so the holes all line up, with the bottom points of the V shapes pointing out. Masking tape (or packaging tape) will work well here. Use Figure 5 as a guide. The V shapes are there to help keep the rotating axle stable.
8. Unfold two paperclips to form an L shape. These will be used to form the axle and hand cranks.
9. Connect the long side of one of the L-shaped paperclips to the bendable iron core using *masking* tape, covering approximately 1/8 inch (.6 cm) of the iron core with tape, as shown in Figure 8. Secure it well so your axle is sturdy. We strongly suggest you use masking tape; other tape might not create a sturdy attachment.

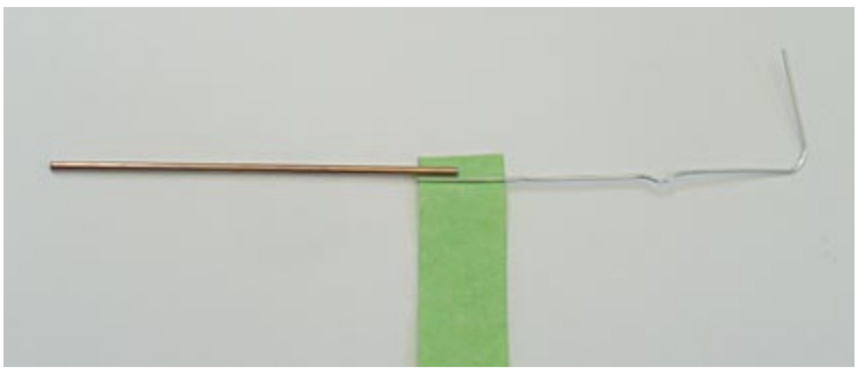

Figure 8. Picture showing how to connect a paperclip unfolded into an L shape with the bendable iron core using masking tape (green in this picture).

10. Complete the axle.
    a. Poke the iron core with paperclip attached through the hole in the V-shaped corrugated cardboard, then through the hole in the box.
    b. Poke the long side of the other L-shaped paper clip through the other V shape and the hole in the box.
    c. Connect the loose paperclip to the iron core using masking tape, as described in step 5.
    d. This completes the axle with cranks on both sides.
11. Set up your wire dispenser so the spool can easily dispense wire to the core. Figure 5 shows a possible setup.
12. You can now prepare to start winding your coil. Attach the end of the magnet wire to the axle with tape. Tape it close to the start of the iron core, on top of the tape used to connect the L-shaped paperclip, keeping 8 inches (20 cm) of magnet wire free to create a lead. The type of tape used is not essential in this step. *Note:* A *lead* (pronounced "leed") is a piece of electric wire that is used to connect one electrical instrument to other electrical instruments. The end of the magnet wire you are taping to the iron core will be called the *start lead* of the coil.
13. Start winding, neatly lining each loop next to the other, starting where the masking tape ends, as shown in Figure 9.
    a. The individual loops might tend to spread out as you wind the coil; use your thumb and pointer finger to make sure the turns stay tight together, one next to the other.
    b. Make a note of how you wind, clockwise or counterclockwise. If you are winding your second coil, make sure to wind in the same direction as you did for the first coil. Rotating in the other direction would change the direction of the induced current.

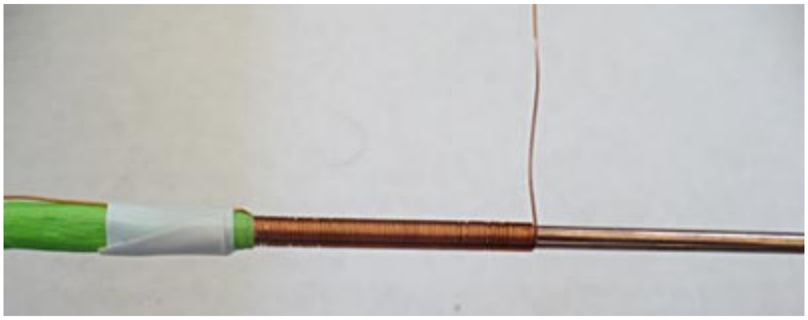

Figure 9. Loops of magnet wire placed neatly, one next to the other, around an iron core starting at a connection of the iron core with the L shape. The green masking tape holds the core and the L shape together to form the axle; the white tape holds the start lead in place.

14. Wind until you reach the other end of the core where the masking tape holds the core and the other paperclip together. Now, continue winding, turning the crank in the *same* direction heading back. This will make your second layer of loops.
15. Continue winding neatly, back and forth, one layer on top of the other, until you finished your sixth layer of loops. *Note:* If you are winding your second coil, stop after winding four layers.
16. Use a small piece of tape to secure the last loops so all the loops stay tight.
17. Cut the magnet wire, leaving a lead of 8 inches (20 cm) of wire free to make electrical connections later. This lead will be referred to as the *end lead* of the coil.
18. Use a small piece of tape and place it around the end lead, creating a little flag. This flag will mark which lead is the end lead of the coil.
19. Undo the tape that holds the start lead to the axle; also undo the masking tape that holds the core and the L shapes together to form the axle. You now have a straight coil with start and end leads.
20. Strip *all* the insulation from the last inch (2.5 cm) of both leads so they can be used to create electrical connections:
    a. Fold the piece of sandpaper in half, with the rough sides facing each other, to make a "sandpaper sandwich," as shown in Figure 10.
    b. Put the end of the magnet wire that you want to strip inside the sandpaper sandwich, as shown in Figure 10. While softly pressing the sandpaper sandwich together, gently rub it over the last inch of the wire, back and forth.
    c. Give the wire a quarter turn and rub some more to remove the coating on all sides of the wire.
    d. The wire is stripped when you can see the copper wire underneath.
    e. Be careful not to press too hard when rubbing or the wire could break.
    f. See this Wire Stripping Tutorial video (#video-striphookupwire) for a demonstration if you are having trouble stripping the insulation.

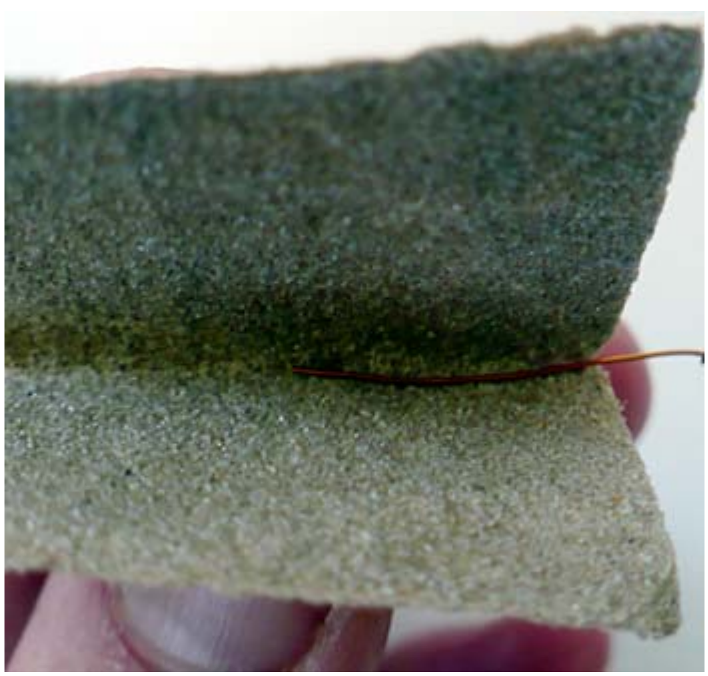

Figure 10. A "sandpaper sandwich" is used to remove the insulation from the ends of the magnet wire.

Tutorial video for stripping insulation from hookup wire.
https://www.youtube.com/watch?v=yDyjVwuy1Ug (https://www.youtube.com/watch?v=yDyjVwuy1Ug)

21. Now bend the coil (or the iron core with magnet wire winded around) in a U shape.
    a. Protect your table with a piece of paper, placed just next to the edge of the table.
    b. Place 1 1/2 inches (4 cm) of coil on the paper, perpendicular to the edge of the table. Hold the coil with one hand on the table while you use your other hand to bend that side 90 degrees down. Note you might need to push quite hard to bend the coil.
    c. Now, place 1 1/2 inches (4 cm) of the other end of the coil on the paper, perpendicular to the edge of the table. Hold the coil with one hand on the table while you use your other hand to bend this side 90 degrees down, resulting in a U shape hanging on the edge of the table, as shown in Figure 11. Your coil is now complete.

Figure 11. A straight coil is bent into a U-shaped coil at the edge of a table with the force of your hand.

Measure the Magnetic Field Configuration Around the Coil

In this section, you will measure and draw the magnetic field configuration around a straight iron core and the U-shaped coil you just finished. Consult the Electromagnetism Tutorial video (https://www.youtube.com/watch?feature=player_embedded&v=V-Gus-qIT74) if you need help on how to execute this section.

In addition to the iron core and the coil, you will need the iron filings, at least one compass, a pen, and a couple of sheets of paper. You can use a camera to take pictures to go on your Science Fair Project Display Boards (http://www.sciencebuddies.org/science-fair-projects/science-fair/science-fair-project-display-boards).

1. Create the first magnetic field configuration, with opposite poles facing the coil or core. *Note*: In this section, "core" will always refer to the straight iron core that comes with your kit, and "coil" will always refer to the U-shaped coil you just wound.
    a. Take a bendable iron core and two neodymium magnets.
    b. Drop the core on a hard floor or table top, or slam it a couple of times against the palm of your hand. The sudden jarring motion of "stopping" will remove all remaining alignment of magnetic domains that might be present in this ferromagnetic material. Consult the Electricity, Magnetism, & Electromagnetism Tutorial: Magnetism (http://www.sciencebuddies.org/science-fair-projects/references/electricity-magnetism-electromagnetism-tutorial#magnetism) if you would like to learn more about ferromagnetic materials and magnetic domains.
    c. Place one magnet at one end of your iron core, with a small piece of cardboard between the core and the magnet, as shown in Figure 12. Place the other magnet and piece of cardboard at the other end, making sure opposite poles face the core.
    d. Use your compass to check if both ends of the core are connected to opposite poles:
        i. Hover your compass over the core, closer to one end. Check which side of the compass needle points to the magnet on this end.
        ii. Hover your compass over the core near the other end. Check if the other side of the compass needle points to the magnet on this end.
        iii. If not, repeat steps 1.b. and 1.c. and check again.

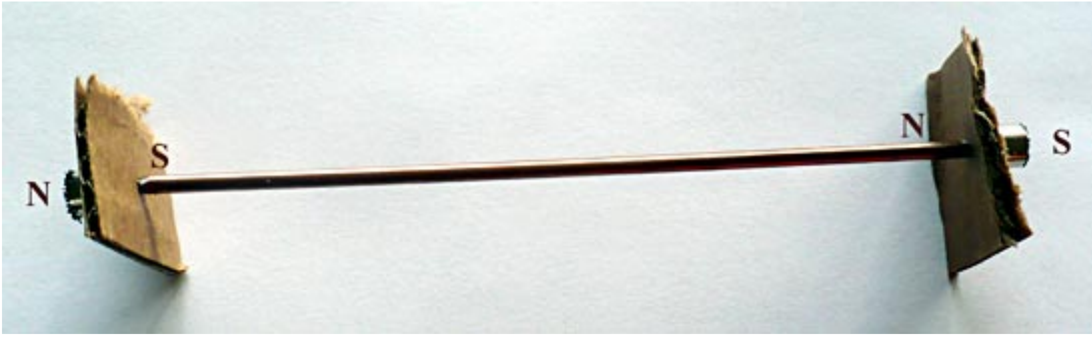

Figure 12. Iron core with magnets and small pieces of cardboard at both ends. The configuration shown has opposite poles facing the core.

2. Make the magnetic field visible using iron filings.
   a. Place a sheet of paper on top of the iron core with magnets attached. The iron core should be beneath the center of the paper atop it.
   b. Sprinkle iron filings evenly in a circular area of about 7 inches (18 cm) diameter in the center of the top paper.
   c. Shake the top paper gently or use your finger to move the iron filings gently around.
   d. Watch magnetic field lines appear.
   e. Note where iron filings align easily with the field lines. This is an indication of a strong field.
   f. Use your compass to confirm the direction of the field lines where needed. *Note*: The needle will always align with the field lines.
   g. Take pictures if you have a camera available.
3. Draw your configuration and magnetic lines on a sheet of paper. See the drawings of the magnetic field around a bar magnet in the Electromagnetism Tutorial video (https://www.youtube.com/watch?feature=player_embedded&v=V-Gus-qIT74) if you need help on how to draw magnetic field lines.
4. Make an educated guess in your lab notebook of how these field lines would continue inside the ferromagnetic material of the iron core to create closed loops. Do you expect the field to be strong (lots of field lines bunched together) or weak inside the iron core?
5. Carefully remove the magnets and cardboard from beneath the paper and set them aside. The magnets will pull the filings with them, so pay attention and try not to spill the filings.
6. Remove the top paper and collect the iron filings back in your tube.
7. Use the field configuration obtained in previous steps to form a hypothesis of what the field might look like when you bend the core in a U shape. This step allows you to refine and test your idea.
   a. Drop your coil on a hard floor or table top or slam it a couple of times against the palm or your hand to remove all remaining magnetic alignment in the material.
   b. Connect the ends of the U-shaped coil you recently wound to the two magnets and small pieces of cardboard, as you did in step 1 if you are testing the first configuration or step 8 if you are testing the second configuration. Figure 13, below, illustrates the result.
   c. Use a compass to detect the direction of the field lines at a particular point. At any spot in the magnetic field, the needle of the compass will always line up with the field lines. You can put your compass on top of the coil to see the direction of the field close to the coil.
   d. Make a drawing of the field around the U-shaped coil.
   e. If you need additional information, you can use your filings to make the field lines visible around the coil. This field is a little more complicated, so make sure you use your compass, in addition to the filings!
   f. Make an educated guess in your lab notebook of how these field lines would continue inside the ferromagnetic material within the coil to create closed loops. Do you expect the field to be strong (lots of field lines bunched together) or weak inside the iron core?

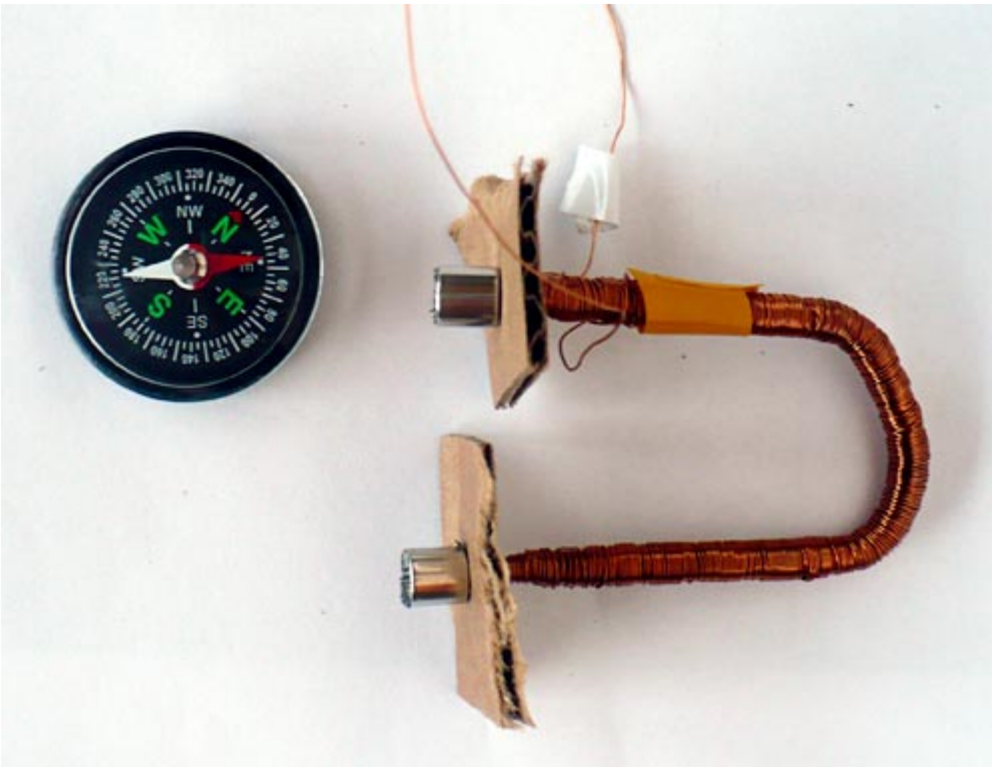

Figure 13. U-shaped coil with magnets and small pieces of cardboard at both ends. A compass is used to detect the magnetic field orientation around the coil.

8. Now you will test your second magnetic field configuration: like poles facing the *core*,.
    a. Repeat step 1, making sure like poles face the core.
    b. Repeat steps 2–6 for the second magnetic field configuration.
9. Now test the second magnetic field configuration for the *coil* by repeating step 7. Be sure like poles face the coil.
10. Copy the table below in your lab notebook and use your drawings to fill in your findings. *Note*: The "area covered by a single winding (or wrap) around the coil" refers to the cross-section of your iron core. As in this project, the core is a long cylinder, this cross section is the same for each of the 900 to 1500 windings around the core and identical to the surface of the circular base of the cylinder iron bar.

	Alternating Poles Pointing Outward	Identical Poles Pointing Outward
Sketch of the field lines around the U-shaped coil.		
Identify the amount of field lines going through the area covered by a single winding. (Plenty – Few – None)		
Identify the orientation of the area covered by a single winding and most of the field lines. (Perpendicular – at an angle – parallel)		

Table 1. Table in which to record your findings with respect to the magnetic field around the coil for two different magnet configurations.

Assemble a Generator

Note: If you used materials from the kit to create a wire spool dispenser, you might need to disassemble *part* of, or your entire wire spool dispenser and repurpose the pieces as you build the generator.

Let Figure 14, below, be your guide through the instructions.

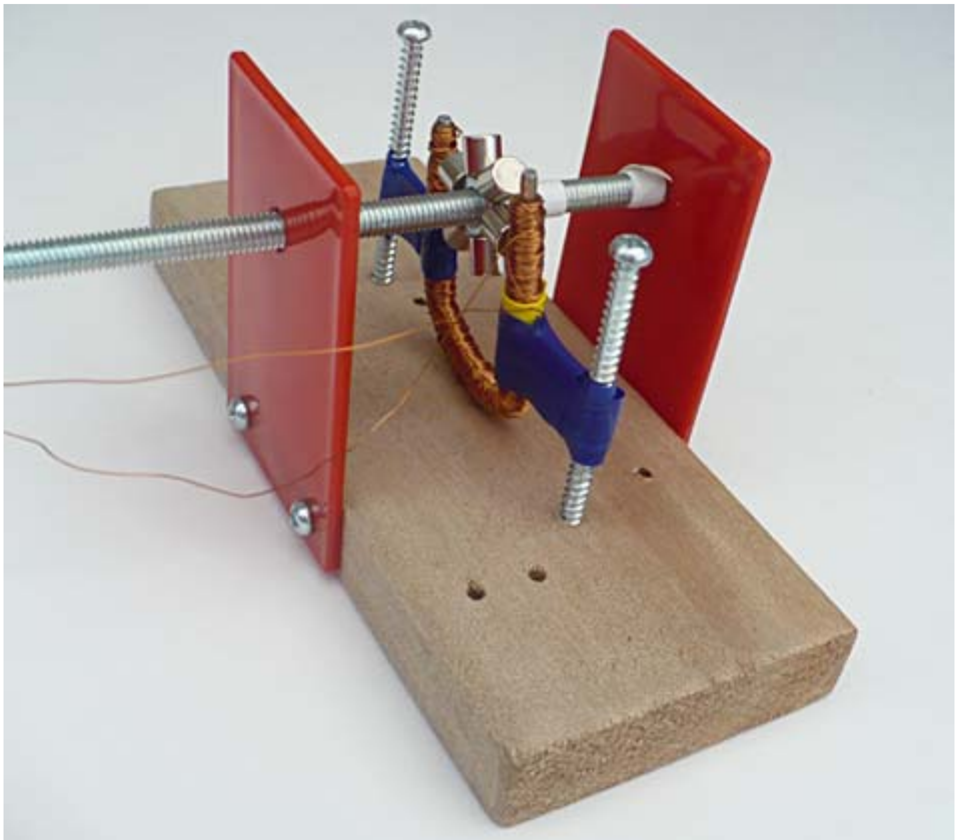

Figure 14. Finished generator using one coil and six neodymium magnets to generate electricity.

1. Find the materials needed to build the basic structure: the pre-drilled wooden block, two red plastic panels, four short screws, three hex nuts, and a long bolt. All of these are shown in Figure 15, below.

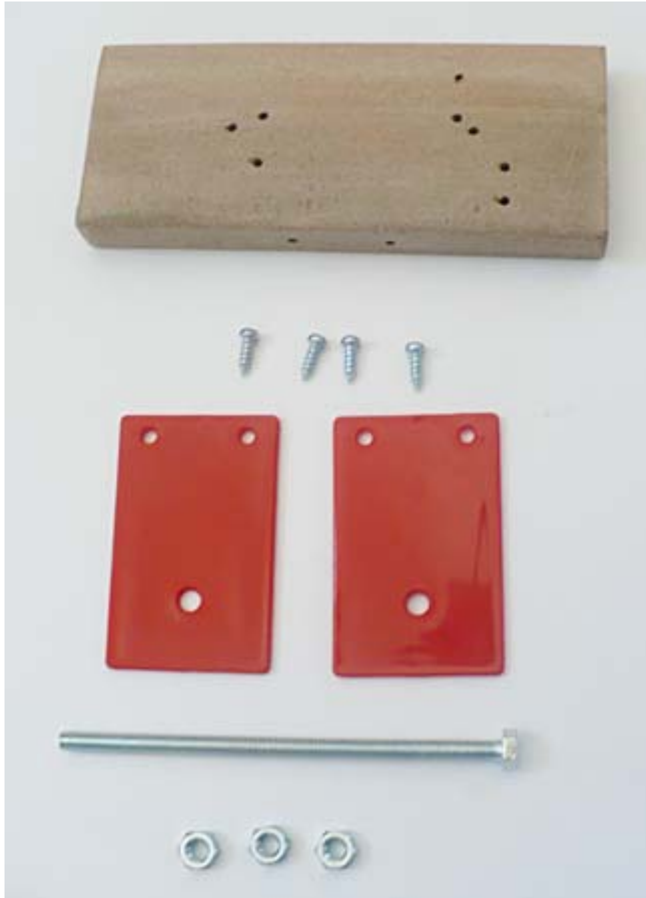

Figure 15. The following items are used to build the basic structure of the generator: pre-drilled wooden block, two red plastic panels, four short screws, three hex nuts, and one large bolt.

2. Attach the red side panels to the sides of the wooden block using the two pre-drilled holes on either side of the wooden block and the four short screws. Use a Phillips screwdriver to secure the panels well.
3. Take the long bolt, place it through the hole of one red panel, thread two hex nuts on the bolt, place the bolt through the hole of the other red panel as far as it can go, and thread the last hex nut on the bolt. This bolt will be referred to as the *shaft* of your generator.
4. In this step, you will use *electrical* tape to keep the bolt and hex nuts in place. Note electrical tape is the preferred type in this step.
    a. Place tape on the far end of the bolt, just inside the red panel, to thicken the screw, as shown in Figure 16, below. This will keep the bolt in place without restricting its ability to rotate, since the bolt will be the central shaft of the generator.
    b. The next hex nut will need to be secured in the middle between the red panels, even with the two center holes drilled in the wooden block, as shown in Figure 16, below. This hex nut will hold the magnets and serve as the *rotor* (or rotating part) of your generator. To secure it well, place the hex nut in this final position, rotate it about 2 mm away from its final position, place two layers of tape on the bolt just next to the hex nut and thread the hex nut back in place on the tape. The hex nut should feel sturdy mounted on the bolt.
    c. The second hex nut mounted between the rotor and the last red side panel will be handy to thread the rotor back in place in case it does get loose. It can be left at any position between the rotor and the red panel. In Figure 16, below, it is placed against the red panel.
    d. Use tape to keep the last hex nut in place on the end of the bolt outside the red panel. This hex nut should be placed more or less in the middle between the red panel and the end of the bolt. It will help thread wire around the shaft (or, see Make It Your Own (#makeityourown) for a variation on this science project where this can be used to install a windmill or a water wheel).

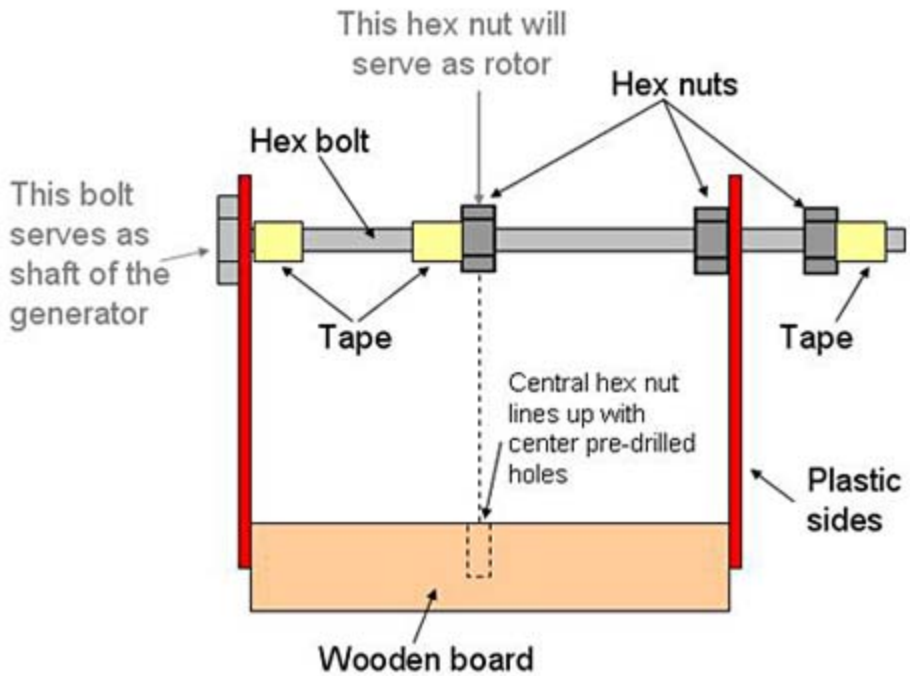

Figure 16. Schematic drawing illustrating where to place the three hex nuts on the central bolt. It indicates how the central hex nut (which will serve as the rotor) is aligned with the central pre-drilled holes and how to use electrical tape to secure objects in place.

5. Finish the rotor by placing six neodymium magnets on the central hex nut, one on each side with alternating poles facing outward, as shown in Figure 17, below. Using this configuration, the magnetic field felt inside the coil will flip with every 60 degrees (or one-sixth of a full turn) of the shaft.
    a. Stack the six neodymium magnets, one on top of another. You might want to cut out small pieces of cardboard and place them between the magnets. The cardboard will help them separate more easily.
    b. Peel one magnet at a time from the top of your stack. *Alternate* whether you attach the "top" or the "bottom" (the side that was stuck to the other magnets in the stack) to the hex nut. This will ensure that you have alternating north-south poles, as shown in Figure 17.
    c. You might want to approach the hex nut from the side (hovering over the central bolt) to avoid the pull and push from the other magnets already on the hex nut.
    d. If using six magnets is difficult, feel free to test your generator with two magnets placed 180 degrees apart on the hex nut. Make sure opposite poles face outward. *Note*: This configuration might provide a very dim light.

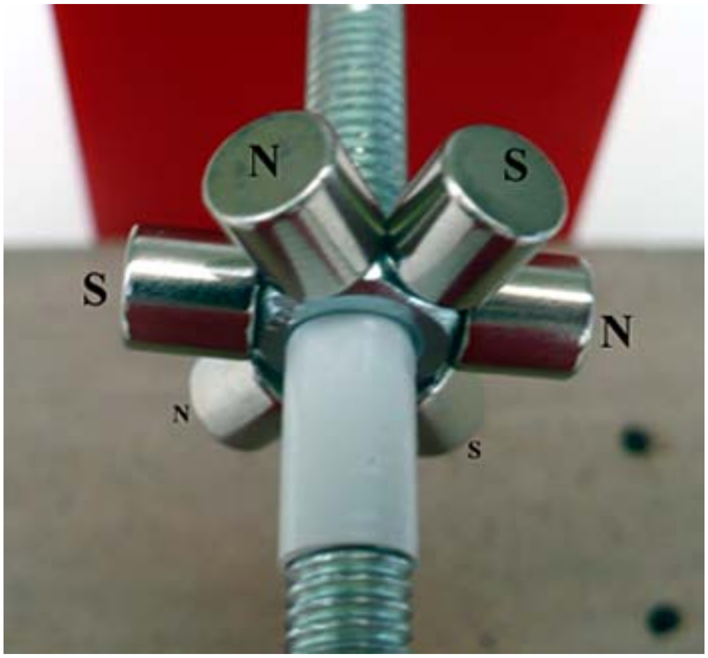

Figure 17. Six neodymium magnets, one on each side of the hex nut, serve as the rotor of the generator. The magnets are placed such that the magnetic pole facing outward alternates south - north - south - north - south - north.

6. Use your compass to check if you placed your neodymium magnets correctly.
    a. Hold the magnet above one magnet and note the direction of the compass needle.
    b. Turn the shaft 60 degrees (one-sixth of a full turn) so the compass faces the next magnet. Note what happened to the needle of your compass while you made the turn. Did it flip? Can you explain why?
    c. Flip magnets, if needed, until the needle flips for every 60 degree turn. Make sure to check all six magnets.
7. Take the U-shaped coil and fine-tune the U-shaped coil so the rotor fits just inside the opening between the legs of the U shape, leaving about 1 mm of space on either side, as shown in Figure 18, below.

Figure 18. Shape the coil so the rotor fits inside the U shape, leaving just enough space to let it turn easily. *Note:* The magnets might pull the U shape toward it.

8. In this step, the U-shaped coil will be securely attached to the support using *masking* tape. Make sure the coil is securely attached to the wooden block. The magnetic forces pushing and pulling on the coil when the generator is operating can be very strong.
    a. Place two screws in the pre-drilled holes in the wooden block on either side of the rotor; these will hold the coil.
    b. Place the U-shaped coil in position, resting on the wooden block with the legs just outside the rotor.
    c. Use masking tape to secure the coil in place. Note electrical tape stretches a little and will not do a good job keeping the coil in place. Figure 19, above, shows a finished generator using one coil and six neodymium magnets to generate electricity.
9. Electrical current can only flow in a closed loop of conductive material. The coil itself is not a closed loop. Electrical connections between the leads of the coil and an LED (light-emitting diode) will close the loop. Nails will be used to ensure good electrical connections.
    a. Tightly wrap the bare copper part of the start lead of the coil around one nail, and the bare copper part of the end lead around another nail. Note that the bare copper of the lead wires (this is the part where you removed the insulation) need to *touch* the metal of the nails to create an electrical connection.
    b. Prepare your LED by attaching a tape flag to the longest leg. This flag will identify the positive side of the LED (the long side). You will need this later in the science project.
    c. Place the two legs of an LED light in the pair of pre-drilled holes next to one of the screws holding the coil, as shown in Figure 19, below. Place the nails in the same holes, making sure each nail touches one leg of the LED to create electrical connections.

Figure 19. Electrical connections between the coil leads and an LED are created using two nails.

10. Test your generator.
    a. Give the shaft a quick turn; does your LED light up?
    b. If you did not see a burst of light, try again, giving the shaft a faster turn.
    c. You might need to dim the light in the room to see the LED, as it might only produce a faint light. Some students need to implement a mechanism that creates fast enough bursts of rotation to generate light. The section " Test Your Generator" can help you implement such mechanism.
11. If your LED does not light up:
    a. Check the electrical connections between the coil leads and the LED. Are the *bare* wires (section where insulation has been removed) *touching* the nails? Does each nail touch one, and only one, leg of the LED? If not, make better connections and try again.
    b. Make sure all the insulation of both lead ends is removed. You should be able to see the bare wire all the way around. If not, remove the remaining insulation and try again.
    c. In case you chose the option to use two magnets in step 5.d., test if switching to six magnets gets your LED to light up.
    d. If your generator is still not working, consider the care you took as you wound the coil: are your loops neatly next to each other? Did you make sure you did not reverse the direction of winding when moving from one layer to the next? If you think you weren't as careful as you could have been, you might want to rewire your coil, or check if you are able to light up an LED connecting several coils together.
12. Make small adjustments where needed:
    a. If your shaft does not rotate easily, do some tinkering to make it rotate more freely.
    b. If your coil is moving while you turn the shaft, secure your coil better so it stays put when the rotor turns.

Test Your Generator

Your LED might light up when you give the shaft a quick turn. To do a scientific test, you will need to create a *reproducible* rotation (meaning, a rotation of similar speed and duration). It is very hard to crank your generator by hand multiple times in exactly the same way. This section describes how to create a mechanism that creates reproducible bursts of rotation using a weight. (You will find other interesting ideas, like creating a windmill or a water wheel in the Make It Your Own (#makeityourown) tab).

1. If you are using a tiny bucket with a handle, you can skip this step. If you are using a disposable cup, you will need to prepare it so it can easily be attached to a string.
    a. Carefully make two holes with the 1-hole puncher or scissors on opposite sides of the cup, near the top edge.

2. Cut a string, about 40 inches (100 cm) long and attach the string to the bucket or plastic cup such that the cup or bucket can carry a mass hanging down from the string. Use Figure 20, below, as your guide.

Figure 20. A cup or bucket hanging from a string will be used to create reproducible rotations of the generator's shaft.

3. Attach the other end of the string securely to the shaft using the hex nut placed outside the red panel, as shown in Figure 21, below.
    a. Wrap the string one time (or a few times if your string is thin) around the shaft near the hex nut.
    b. Screw the hex nut over the string.
    c. Use tape, if needed, to further secure the string and the hex nut.
    d. Make sure the string does not slip, but winds up around the shaft if you turn the shaft, as shown in Figure 21, below.

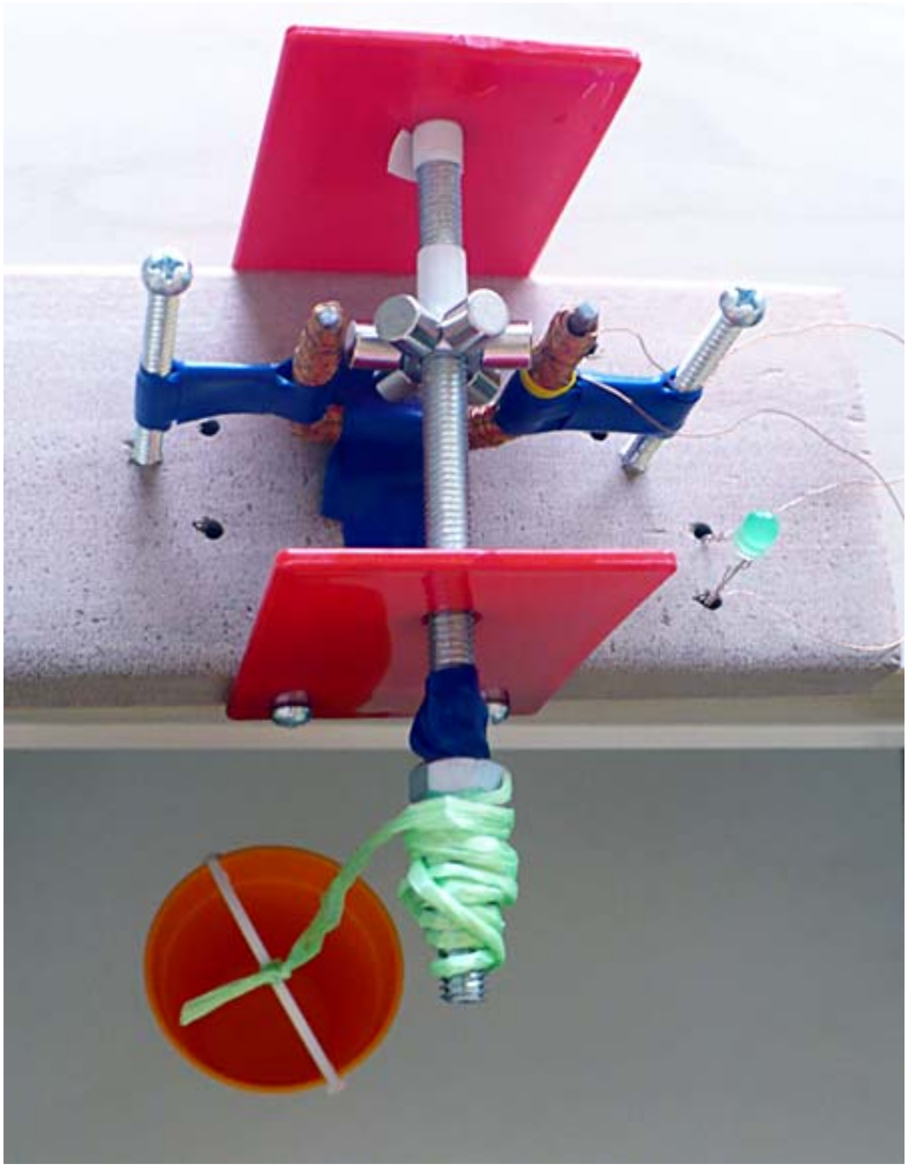

Figure 21. Electric generator using a bucket in which mass can be placed to create rotation.

4. Place the generator at the edge of a table, as shown in Figure 21, above. This allows the bucket to freely roll down, creating a rotation of the shaft.
5. Use a mass of approximately 90 grams (g) in the bucket to create rotation. This mass is equivalent to about 18 nickels. Table 1, below, lists the mass of different United States coins so you can find a different combination of coins, if needed.

Coin	Penny	Nickel	Dime	Quarter	Half Dollar	Presidential $1 Coin	Native American $1 Coin
Mass	2.50 g	5.00 g	2.27 g	5.67 g	11.34 g	8.10 g	8.10 g

Table 2. Table listing several United States coins and their masses, expressed in grams.

6. Test your generator:
   a. Wind the string of the bucket all the way up.
   b. Fill the bucket with the mass as you hold the bucket.
   c. Let it roll down while looking at the LED.
   d. Watch if your LED lights up.
7. Make adjustments where needed. For instance, if your LED was lighting up using a hand crank, but is not with your bucket, or if the shaft does not turn well with your mass, you might need to add some mass to the bucket.

Compare Generated Electricity Versus Magnet Configurations

Now you have everything in place to test your generator with two permanent magnet configurations. The configurations you are going to test are:

1. The permanent magnets placed on the rotor such that *alternating* poles face outward.
2. The permanent magnets placed on the rotor such that *identical* poles face outward.

Technical Note

This generator induces fluctuating electricity. In scientific language, this is called an *alternating current* in the loop, or an *alternating voltage* over the coil. The graph below shows how the induced electricity changes over time during a little more than 1 1/2 cycles.

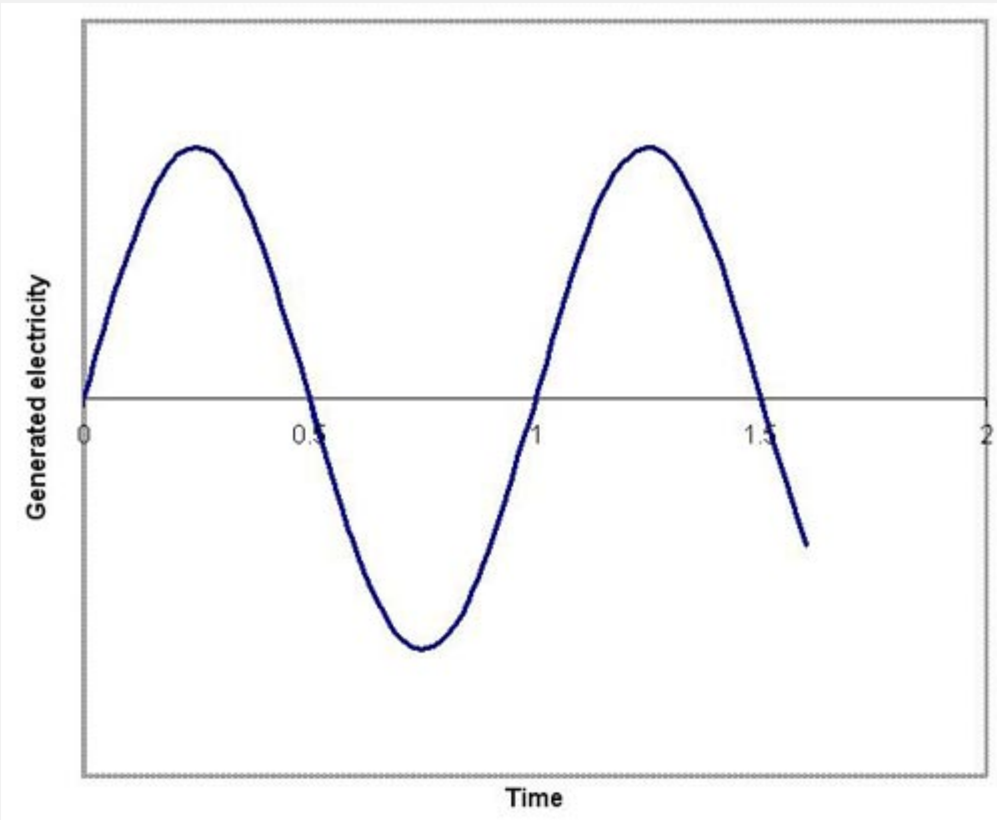

Figure 22. A graph of induced electricity over time. The part above the time axis reflects a positive induced voltage, or a current in one direction; the part below the time axis reflects a negative voltage, or a current in the opposite direction.

Multimeters that support measurements of alternating current or alternating voltage accurate enough to be used in this electronics science project are expensive. If you have one available or can use an oscilloscope to visualize how the generated current or induced voltage changes over time, do it!

As an alternative, this science project uses a qualitative measurement, being whether or not the generator can illuminate an LED light.

Consult the Electricity, Magnetism, & Electromagnetism Tutorial: DC vs AC (http://www.sciencebuddies.org/science-fair-projects/references/electricity-magnetism-electromagnetism-tutorial#dcvsac) for a more in-depth explanation of alternating current.

1. Copy the following table in your lab notebook. You will use it to record your findings.

	Alternating Opposite Poles Pointing Outward	Identical Poles Pointing Outward
Trial 1		
Trial 2		
Trial 3		

Table 3. Table to record whether or not the LED lights up with different configurations of permanent magnets on the rotor.

2. Use alternating south and north poles facing outward for your first test configuration. This is the configuration you used to give your generator a first test (step 10 of section Assemble a Generator). The field in the coil will be created by *alternating* poles being close to the coil legs. *Note*: Depending on your choice in step 5.d. of the section Assemble a Generator, you currently have two or six magnets attached to the rotor. Note the number of magnets used for your trials down in your lab notebook.
3. Test this magnetic field configuration three times. For each trial, you will:
    a. Wind the string of the bucket all the way up.
    b. Fill the bucket with the mass as you hold the bucket.
    c. Let it roll down while looking at the LED.
    d. Watch if your LED lights up.
    e. Record your findings in your lab notebook.
4. Now remove the six magnets from the central hex nut and put them back on the hex nut so all poles facing outward are identical. The field in the coil will be created by *like* poles being close to the coil legs. *Note*: If you used two magnets in step 2, use two magnets again here, both having identical poles facing outward.
    a. Stack the six neodymium magnets, one on top of another, with small pieces of cardboard between the magnets. The cardboard will allow for easier separation.
    b. Peel one magnet at a time from the top of your stack, always attaching the same side (the side that was stuck to the other magnets in the stack, or the side that was not stuck to other magnets) to the hex nut. This will ensure you have identical poles facing outward.
    c. You might want to approach the hex nut from the side (hovering over the central bolt) to avoid the pull and push from the other magnets already on the hex nut.
    d. After you have moved all the magnets to the hex nut, use your compass to check if the poles facing outward are all identical.
5. Repeat step 3 for this configuration. Don't forget to perform three trials.
6. Analyze your results:
    a. Do you get consistent results over the three trials?
    b. Look back at your results noted down in the table you made similar to Table 1, listing characteristics of the magnetic field generated around the coil with the two different permanent magnet configurations. Does the result of your generator test, together with your magnetic field line identification, support what you learned about how electricity is created when magnets move in the vicinity of a closed loop of wire?
    c. Read over the Background (#background) information again if your results are puzzling. If it is still unclear, do not hesitate to ask your science teacher or use the Science Buddies Ask an Expert: Answers to Your Science Questions (http://www.sciencebuddies.org/science-fair-projects/ask-an-expert-intro) advice forums.

Frequently Asked Questions (FAQ)

FAQ for this Project Idea available online at https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p079/electricity-electronics/manipulating-magnets-to-improve-generator-output#help.