



Shed Light on Electric Generators: Do More Coils Generate More Electricity?

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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 two iron cores—one with six layers of wire and one with four layers of wire, each with 200–250 loops 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 2 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).

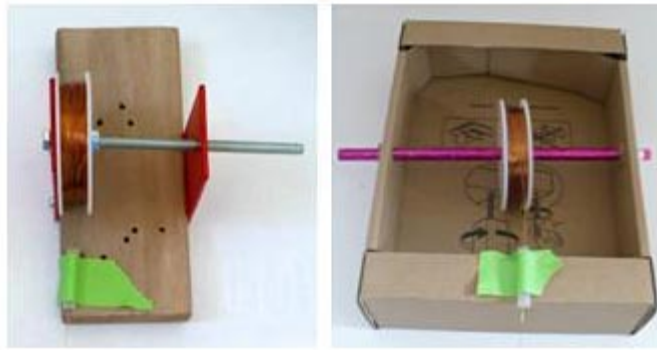


Figure 2. Pictures of wire dispensers made from materials included in the kit (left) or from household materials (right).

Note: If you use materials from your kit for a wire spool dispenser, you will probably need to disassemble it once the coils have been wound at the end of the next section, as parts might be needed to build the electric generator. This is not an issue if you plan to wind both coils before building the generator. However, if you would rather first test your generator with one coil, you might want to build a wire dispenser from household materials instead.

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 3 be your guide throughout the instructions.

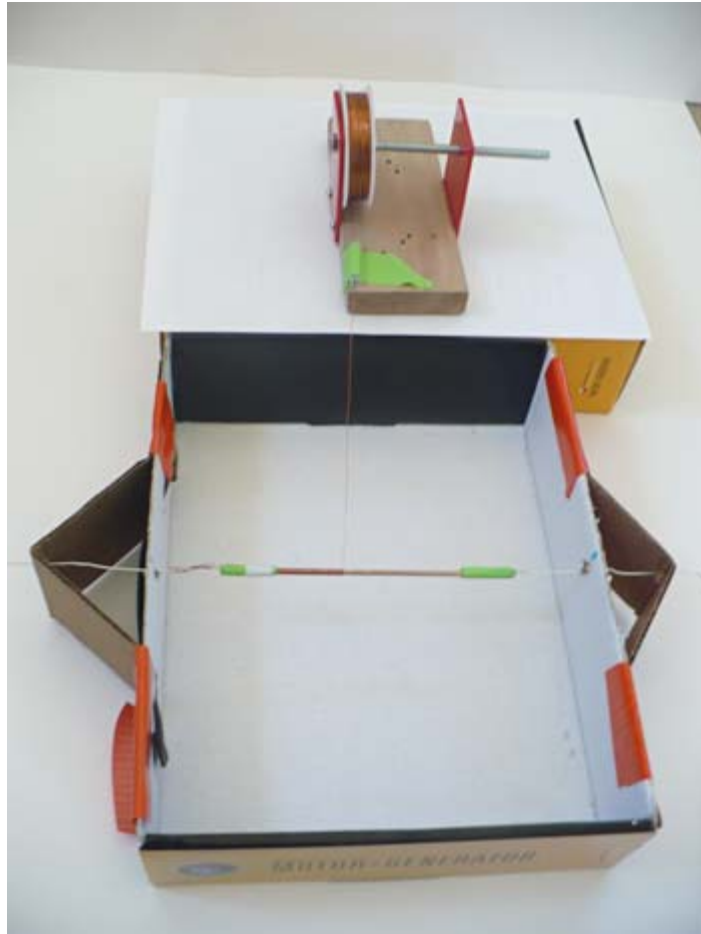


Figure 3. A coil winder like the one depicted here helps wind an iron core neatly with magnet wire.

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 4.
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 4. 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, so when you're finished, you have four equal rectangles and the folds create a V shape with flaps, as shown in Figure 5.
6. Poke a hole about 1/2 inch (1.3 cm) below the edge in the middle fold.



Figure 5. 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 3 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 6. Secure it well so your axle is sturdy. We strongly suggest you use masking tape; other tape might not create a sturdy attachment.

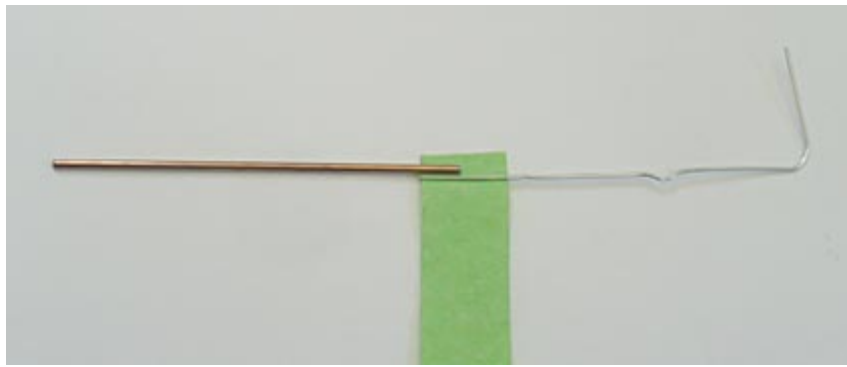


Figure 6. Picture showing how to connect a paperclip unfolded into an L shape with the bendable iron core using masking tape (green in this picture).

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 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 3 shows a possible setup.
12. You can now 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 7.
 - 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.

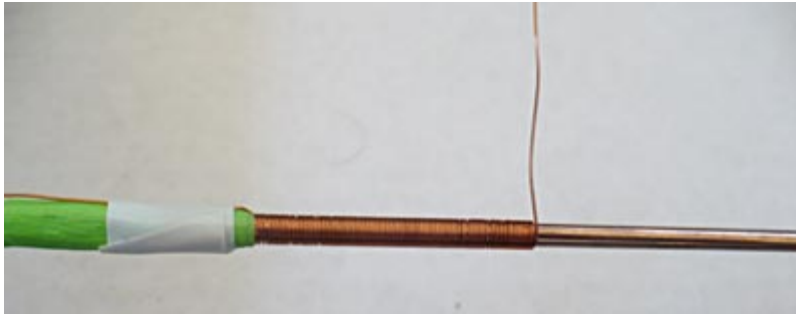


Figure 7. Loops of magnet wire placed neatly, one next to the other, around an iron core starting at a connection of the iron core with the L shape. The green masking tape holds the core and the L shape together to form the axle; the white tape holds the start lead in place.

14. Wind until you reach the other end of the core. 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 8.
 - b. Put the end of the magnet wire that you want to strip inside the sandpaper sandwich, as shown in Figure 8. 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 the Science Buddies [Wire Stripping Tutorial video](#) ([#video-stripmagnetwire](#)) for a demonstration if you are having trouble stripping the insulation.



Figure 8. A "sandpaper sandwich" is used to remove the insulation from the ends of the magnet wire.

21. This finishes your first coil. You can choose to instantly wind your second coil (i.e. repeat steps 8–21, now only coiling four layers of magnet wire on the iron core in stead of six layers, or first build your generator and coil a second core later.

Assemble a Generator with One Coil

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 9 be your guide through the instructions.

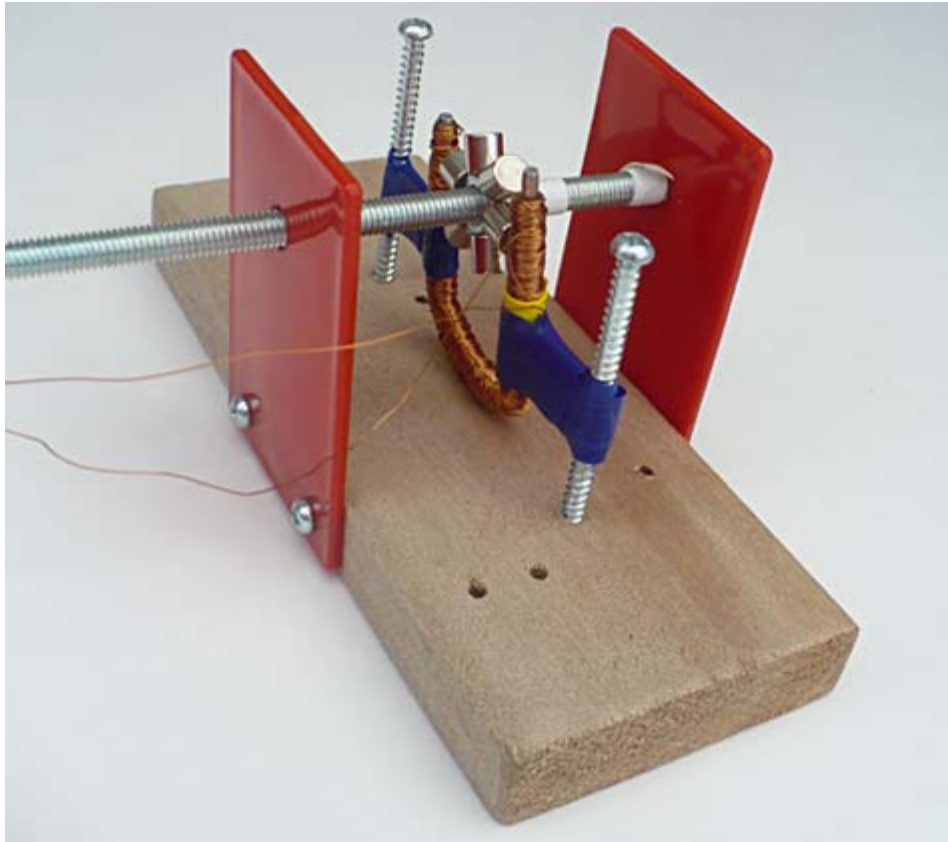


Figure 9. Finished generator using one coil and six neodymium magnets to generate electricity.

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 10.

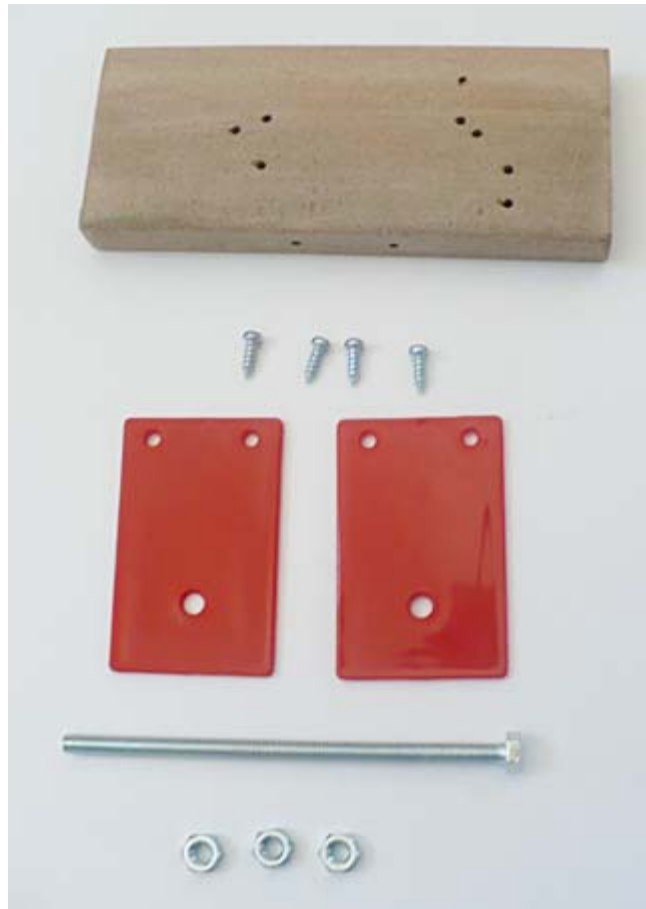


Figure 10. The following items are used to build the basic structure of the generator: pre-drilled wooden block, two red plastic panels, four short screws, three hex nuts, and one large bolt.

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 11. 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 11. 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 11, 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, for a variation on this science project see [Make It Your Own](#) ([#makeityourown](#)), this can be used to install a windmill or a water wheel.

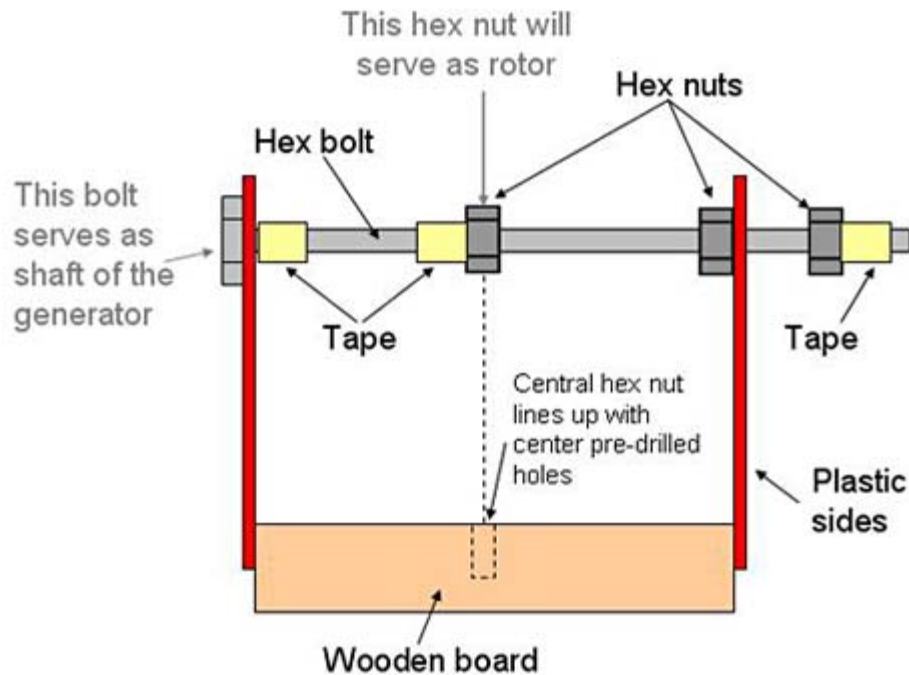


Figure 11. Schematic drawing illustrating where to place the three hex nuts on the central bolt. It indicates how the central hex nut (which will serve as the rotor) is aligned with the central pre-drilled holes and how to use tape to secure objects in place.

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 12. 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 12.
 - 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.

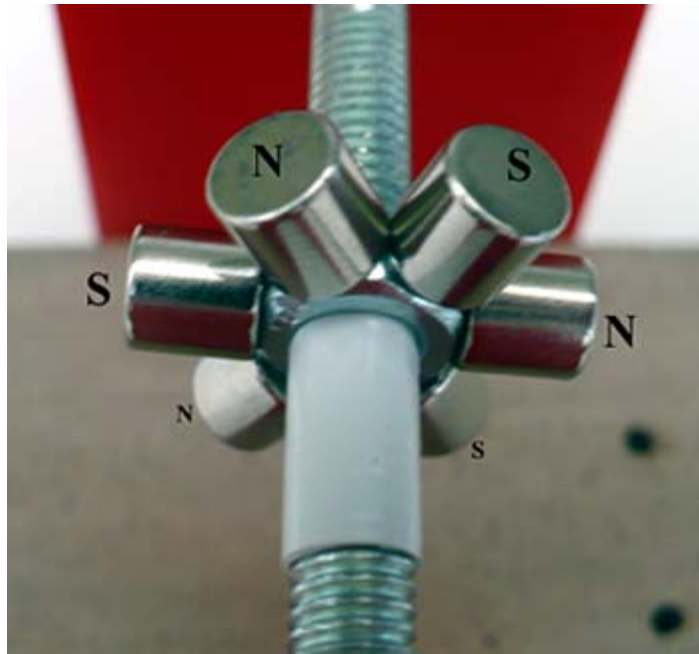


Figure 12. Six neodymium magnets, one on each side of the hex nut, serve as the rotor of the generator. The magnets are placed such that the magnetic pole facing outward alternates south – north – south – north – south – north.

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. Now bend one straight coil (a straight iron core with magnet wire wound around) into a U-shaped coil.
 - 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 13.



Figure 13. A straight coil is bent into a U-shaped coil at the edge of a table with the force of your hand.

8. Fine-tune your 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 14.



Figure 14. 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.

9. 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 9, above, shows a finished generator using one coil and six neodymium magnets to generate electricity.
10. 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 15. Place the nails in the same holes, making sure each nail touches one leg of the LED to create electrical connections.

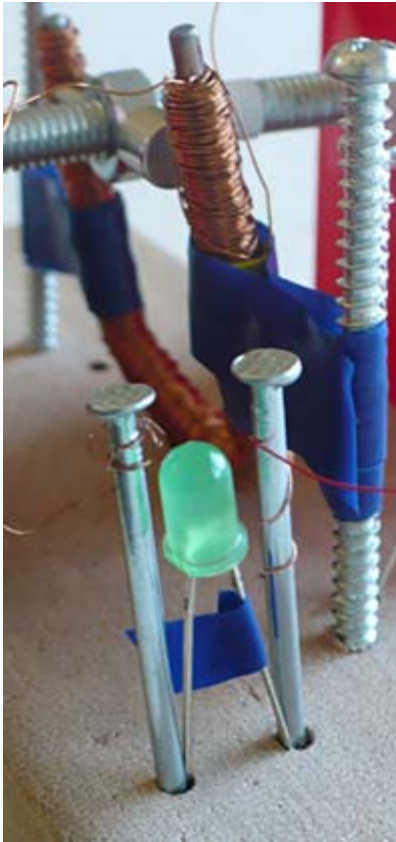


Figure 15. Electrical connections between the coil leads and an LED are created using two nails.

11. 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.
12. 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. 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.
13. 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 16 as your guide.



Figure 16. 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 17.
 - 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 17.

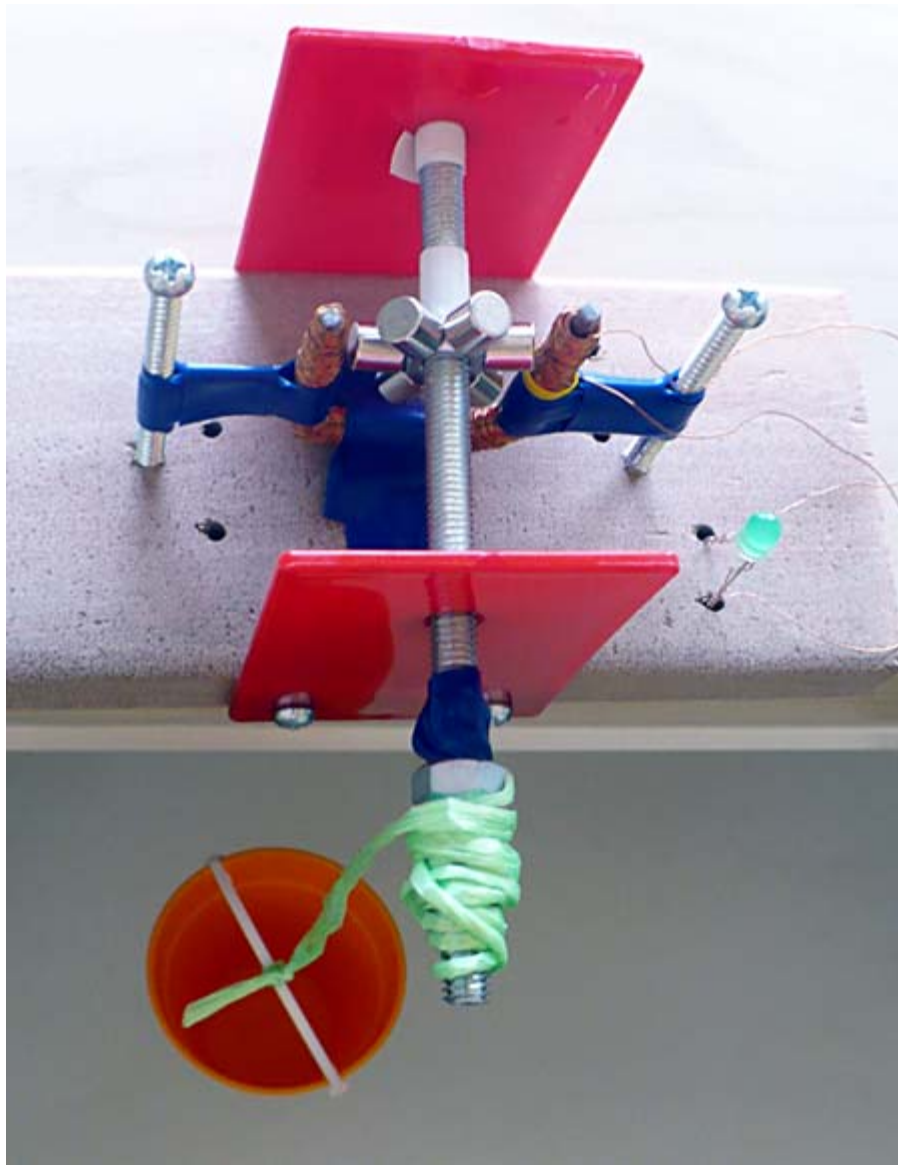


Figure 17. Electric generator using a bucket in which mass can be placed to create rotation.

4. Place the generator at the edge of a table, as shown in Figure 17, 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 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 1. 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.

Add a Second Coil to the Generator

In the previous section, you made a generator with one coil, one LED, and a mechanism to make the shaft turn. If you successfully wired your iron core, the generator should be able to generate enough electricity to light up one LED. In this section, you will study what happens when you add a second coil or use one coil with fewer loops.

1. If you did not wire a second bendable iron core with *four* layers of magnet wire, do it now. Review the section [Wind the Coils](#) (#windthecoils) if you need instructions. Make sure to be thorough; a nicely wound coil is essential to create a good working generator.
2. This second coil will be attached to the red side panel and will rest on a cardboard support. Use Figure 18 as your guide.



Figure 18. Generator using two coils to generate electricity. Note that some tape has been removed for the purposes of this picture, to make the cardboard support visible.

3. Make a cardboard support for the second coil.
 - a. Take a piece of cardboard and fold it back and forth several times to create a layered cardboard support for the coil. Your support will need to be approximately 3/4 inch (2 cm) high and 3/4 inch (2 cm) wide. Hold it together with masking or packaging tape. See Figure 18, above.
 - b. Attach the support to the wooden block next to one red side panel, as shown in Figure 18, above.
4. Hold the U-shaped coil in a position such that:
 - a. The flat part between the legs of the U touches the red side panel,
 - b. One leg of the U shape rests on the cardboard support built in the previous step, and
 - c. The opening of your U-shaped coil goes around the rotor.
5. Check if both coils will create electricity simultaneously. Remember, the coils create bursts of electricity. You will want to place the second coil so the two coils create a burst of electricity at the same time. For this to happen, magnets need to approach the coil legs at the same time and be between coil legs at the same time, as illustrated in Figure 19.

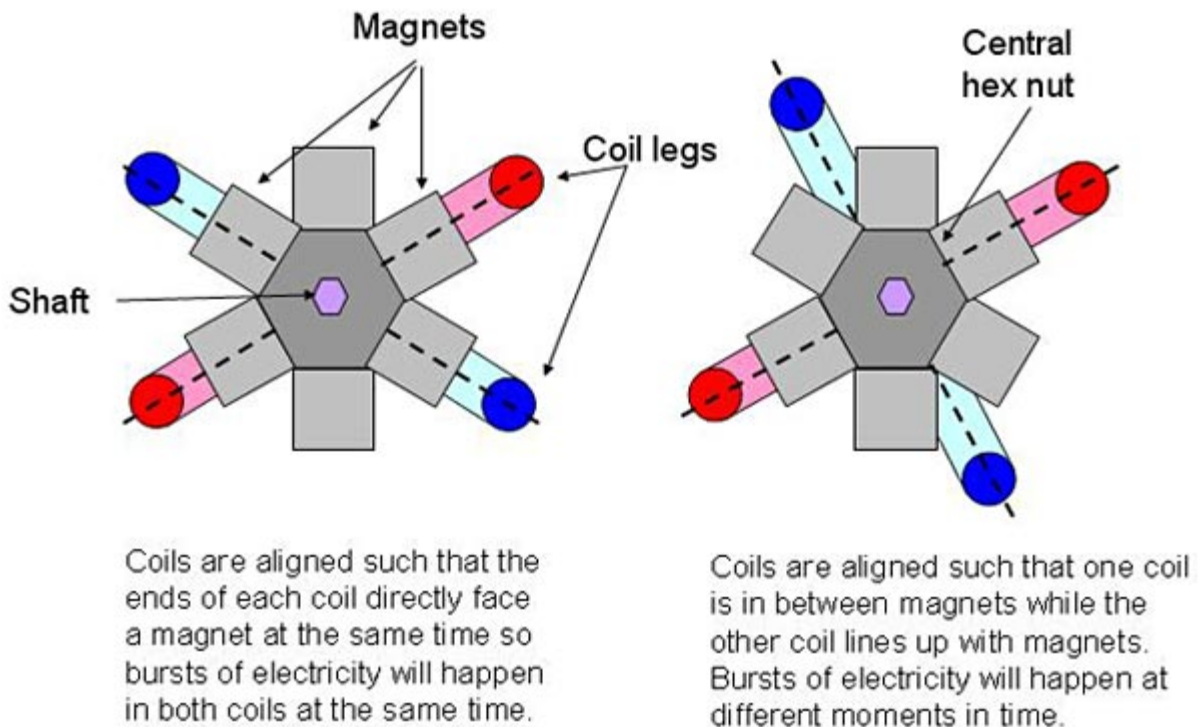


Figure 19. The figure on the left shows a drawing where the legs of both the blue and the red coil face magnets at a given moment in time. With this configuration, bursts of electricity will be produced simultaneously in both coils. In the drawing on the right, the one coil is between magnets when the other is lined up with the magnets. This configuration will not lead to simultaneous bursts of electricity created in the coils.

6. Use *masking* tape to secure the coil in this position. You might need to use a lot of tape to secure the coil in position (as evidenced in Figure 19, above), since the neodymium magnets will create a very strong pull and push on the coil when the generator is in use.

Compare Generated Electricity Versus Coil Configuration

To evaluate how the amount of generated electricity changes when using different numbers of wire loops (or wire wraps), you will test the following coil configurations:

- Coil 1 only (this is the coil with six layers wire wraps)
- Coil 2 only (this is the coil with four layers of wire wraps)
- Connecting the end lead of coil 1 to the start lead of coil 2
- Connecting the end lead of coil 1 to the end lead of coil 2

These tests will show whether or not the generator can power one LED, the first of two LEDs placed in series, the second of two LED lights placed in series, or both LEDs placed in series.

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.

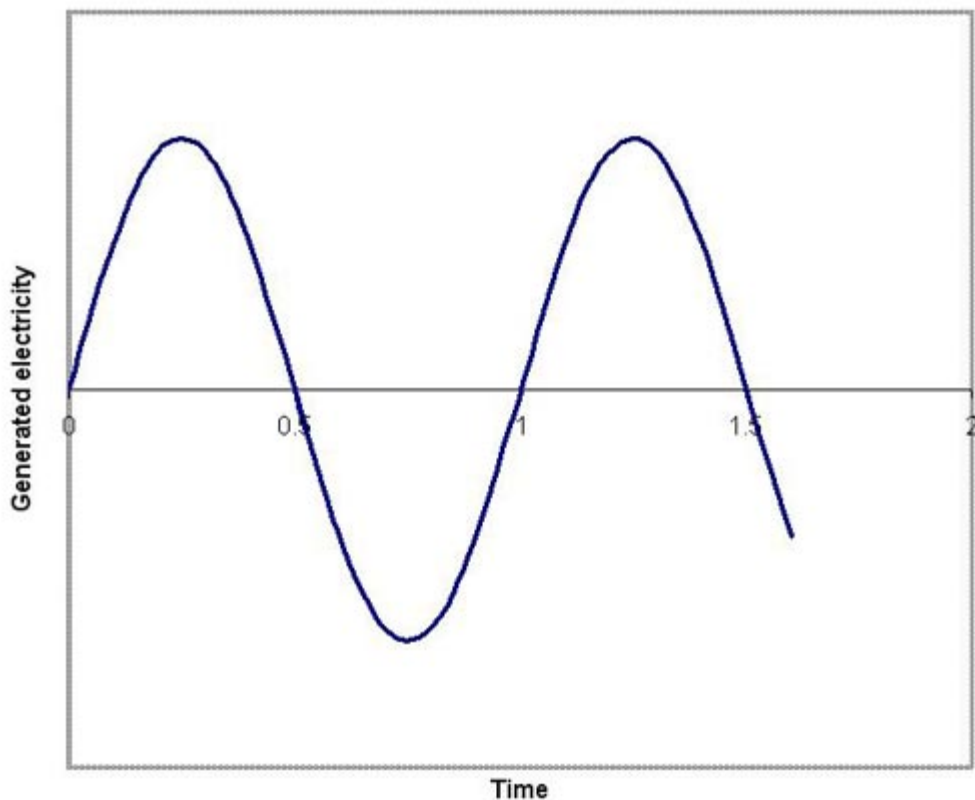


Figure 20. A graph of induced electricity over time. The part above the time axis reflects a positive induced voltage, or a current in one direction; the part below the time axis reflects a negative voltage, or a current in the opposite direction.

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. The number of LEDs placed in series that the generator can illuminate is a measurement of the peak (or maximum) amount of voltage generated.

Consult the [Electricity, Magnetism, & Electromagnetism Tutorial](http://www.sciencebuddies.org/science-fair-projects/references/electricity-magnetism-electromagnetism-tutorial#dcvsac) (<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.

			Coil 1 only (6 layers of coiled wire)	Coil 2 only (4 layers of coiled wire)	End lead of coil 1 connected to start lead of coil 2	End lead of coil 1 connected to end lead of coil 2
1 LED		Trial 1				
		Trial 2				
		Trial 3				
2 LEDs placed in series	1st LED	Trial 1				
		Trial 2				
		Trial 3				
	2nd LED	Trial 1				
		Trial 2				
		Trial 3				

Table 2. Table in which to record whether or not the LED(s) light up with different combinations of coils connected in the circuit.

2. You will test each combination 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(s).
 - d. Record your observations in your data table.
3. To test a coil with one LED:
 - a. Connect the start lead of one of the coils to a nail and the end lead to another nail.
 - b. Put each of these nails together with one leg of an LED in a pair of pre-drilled holes.
 - c. Test three times, completing steps 2.a.–2.d.
4. To test a coil with two LEDs placed in series:
 - a. Leave the leads of the coil connected to the nails.
 - b. Take two more nails and create an electric connection using a new piece of wire that is about 3 inches (7.6 cm) long. *Note:* Do not forget to remove the insulation from the ends of this extra piece of wire so electricity can flow from one nail, through the wire, to the other nail.
 - c. Place each leg of one LED in one set of pre-drilled holes, the legs of a second LED in a second pair of pre-drilled holes, making sure the flagged legs (the longer legs of the LEDs, or the positive sides of the LEDs) face the same side (e.g. away from you or both to the right), as shown in Figure 21. LEDs only allow current to pass through in one direction. For that reason, it is important to have the short leg of one LED connected with the long leg of the other LED.
 - d. Close the circuit by:

- i. Placing the nail with the start lead of the coil into the first hole together with an LED leg,
 - ii. Connecting the two LEDs electrically using the extra two nails connected with the extra piece of wire
(Note: If placed correctly, this should connect one flagged LED leg and one unflagged LED leg), and
 - iii. Placing the nail with the end lead of the coil into the last hole together with an LED leg.
- e. Test three times, completing steps 2.a.–2.d.

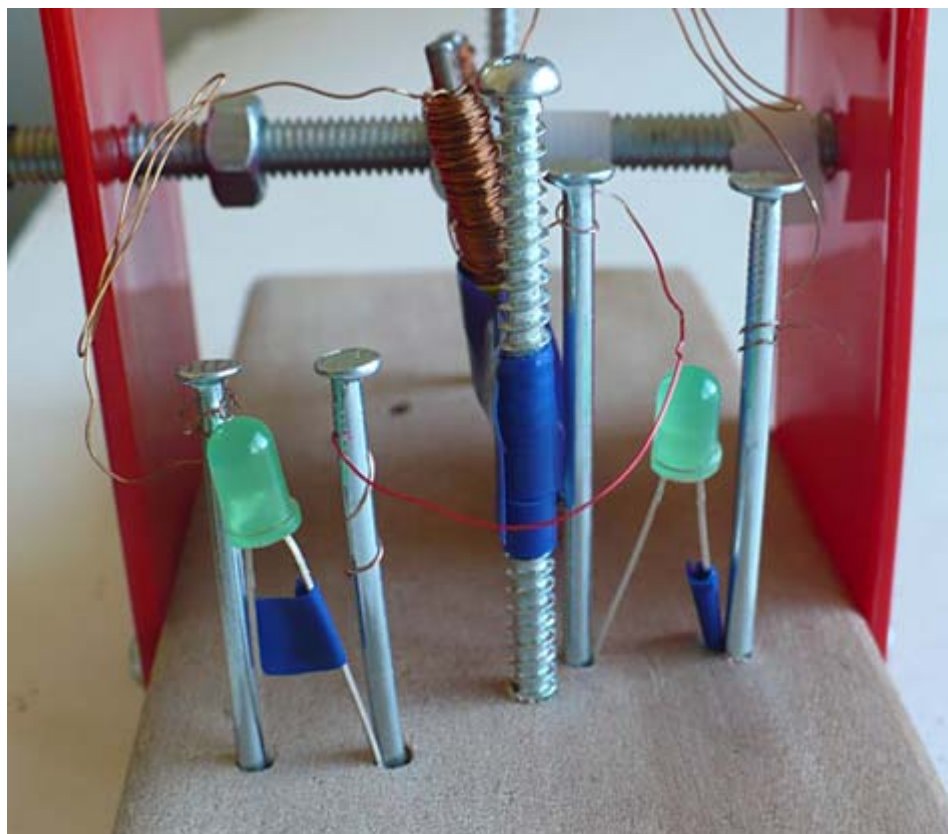


Figure 21. Two LEDs connected in series using two nails and an extra piece of wire. Note that the long (flagged) leg of one LED is connected to the short (unflagged) leg of the other LED.

5. Connect the end lead of one coil to the start lead of the other. Remember, you flagged the end lead of each coil.
Twisting the ends of the leads together will make a secure electrical connection.
 - a. Repeat step 3 with this coil combination to test if this configuration will illuminate one LED.
 - b. Repeat step 4 with this coil combination to test if this configuration will illuminate LEDs placed in series.
 - c. Record your observations in your lab notebook.
6. Now connect the two coils' end leads together. Choose one of the free leads as start lead and the other as end lead of the "connected coil" and test if this configuration will illuminate one LED and/or two LEDs placed in series.
 - a. Repeat step 3 with this coil combination to test if this configuration will illuminate one LED.
 - b. Repeat step 4 with this coil combination to test if this configuration will illuminate LEDs placed in series.
 - c. Record your observations in your lab notebook.
7. Analyze your results. Do you get consistent results over the three trials? Do your results support what you learned about how electricity is created when magnets move in the vicinity of a closed loop of wire? Read over the information in the [Background](#) (#background) tab 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_p078/electricity-electronics/electric-generators-do-more-coils-generate-more-electricity#help.