Human-Powered Energy

https://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p009/energy-power/human-powered-energy (http://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p009/energy-power/human-powered-energy)

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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.

Building Your Generator

1. First you will need to build the "coil form," the paper tube that you will use to wrap your wire coil. To start, you will make a small tube that acts as a spacer between the magnet and the actual coil form to ensure the coil form is big enough and the magnets do not get stuck.
    a. Cut a piece of card stock that is roughly 7 centimeters (cm) x 15 cm, as shown in Figure 3.
    b. Using all six magnets stacked together as a guide, roll the card stock *tightly* into a tube, as shown in Figure 3 (the resulting tube should be 7 cm long).

i. **Important**: Remember to follow all the safety rules listed above for neodymium magnets.
ii. If your magnets come with small, plastic spacers between them, carefully remove the spacers from the stack before using the magnets as a guide to create the tube.

c. Use Scotch tape to secure the tube in place, as shown in Figure 3.

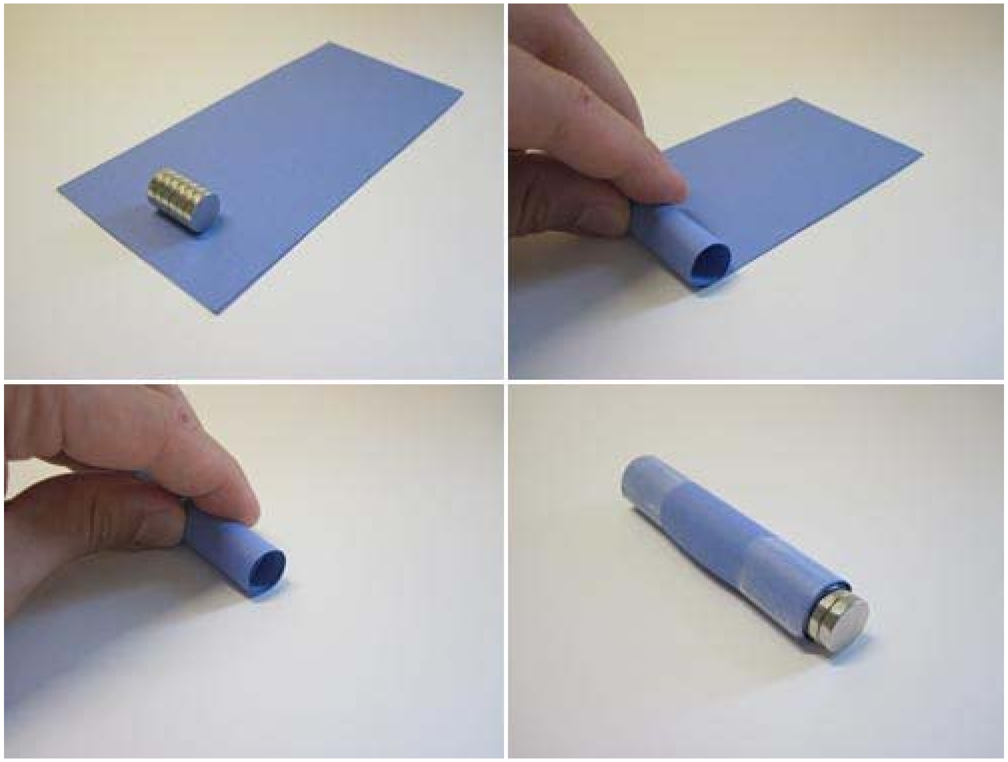


Figure 3. Roll a 7 x 15 cm piece of card stock into a tube, using the magnets as a guide.

2. Use the tube you made in step 1 as a guide to make a second, larger tube. This is the tube you will actually use as your coil form. The magnets will be able to easily slide back and forth in the larger tube without getting stuck.
    a. Cut a *second* piece of card stock that is also 7 x 15 cm.
    b. Using your first tube as a guide, roll the second piece of card stock into a tube, as shown in Figure 4.
    c. Use tape to hold the tube in place, and remove the inner tube from the outer tube, as shown in Figure 4.
    d. When you are done, you can set the smaller tube and stack of magnets aside.

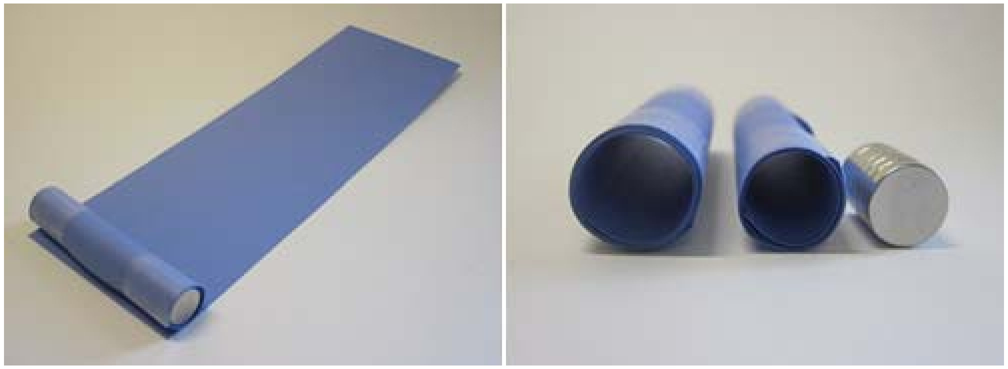


Figure 4. Using the first tube as a guide, roll a second piece of card stock into a slightly larger tube.

3. Add cardboard circles to the sides of your coil form (the larger tube you just made) to act as guides for wrapping wire around your coil form. All sub-steps are shown in Figure 5.
    a. Cut two squares of cardboard, roughly 7 x 7 cm.
    b. Use a pen or pencil to trace one of the circular ends of your coil form onto the middle of one piece of cardboard.
    c. Sketch a larger circle that reaches the edges of the cardboard square around the smaller circle (this circle does not need to be exact).
    d. Use a hobby knife to cut out the smaller, inner circle.
        i. **Important**: Be very careful when using the knife. Young children should have adult supervision. Be careful not to cut into the surface you are working on, like a table top. You may want to use a scrap piece of cardboard or a cutting mat.
    e. Use the hobby knife or scissors to cut out the larger, outer circle.
    f. Repeat steps 3.b.–3.e. for the other piece of cardboard.
    g. Press both pieces of cardboard onto the ends of your coil form, placing them about 1.7 cm apart (just far enough for the stack of all six magnets to fit in between them).
        i. *Note:* If the cardboard pieces do not easily fit around the coil form, you can carefully use the knife to make the inner circles slightly larger. You do not want to damage the coil form by forcing it in the circle.
    h. Use glue to secure both cardboard cutouts in place on the coil form. Wait for the glue to dry completely before you continue to step 4.

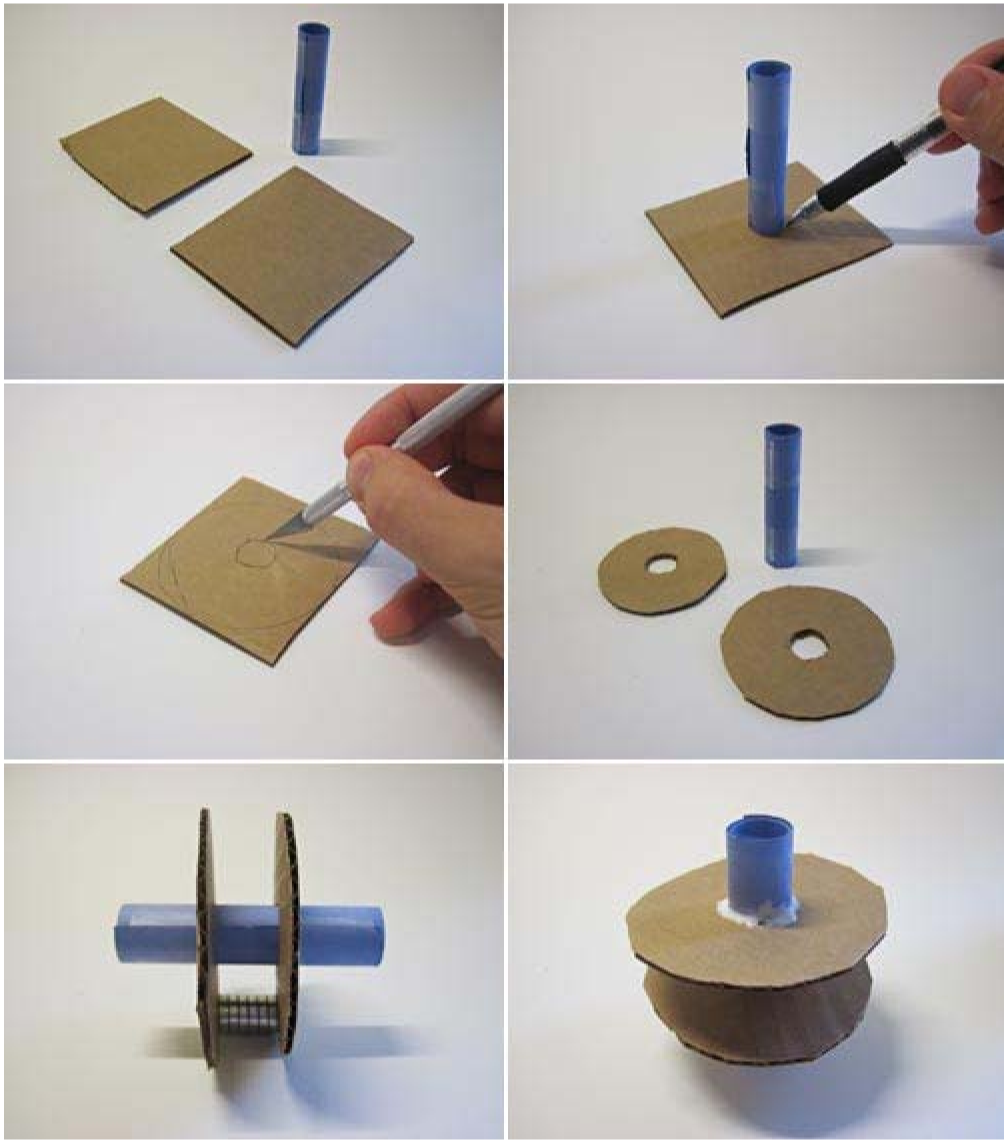


Figure 5. Cut out cardboard circles and glue them onto your coil form (the larger card stock tube), as shown here. *Note:* The bottom left image shows the stack of magnets so you know how far apart to space the cardboard pieces — the magnets will not actually stay in this position.

4. Wind wire around your coil form.
    a. Unwrap about 60 cm of magnet wire from the spool it came in (do not cut the wire yet!).

b. Use tape to secure the wire to the inside of one of the pieces of cardboard, about 30 cm from the end of the wire. This means you should have about 30 cm of wire dangling off of your coil form, as shown in Figure 6.
c. Carefully and *tightly* wrap the wire around the coil form, as shown in Figure 7, below. Count the number of coil wraps you make as you go — you need to complete a total of approximately *1,500* coil wraps. Make sure that the 30 cm segment of dangling wire stays free and does not get wrapped up in the coil; you will need to access it later. Also, make sure that you always continue to wrap the wire in the same direction—do not switch directions or your generator will not work.
    i. Completing 1,500 coil wraps can take a while to do by hand, so be patient. Do your best to keep track of the number of wraps, but you do not need to do *exactly* 1,500. It might help to put a tick mark down for every 100th wrap on a piece of paper so you do not completely lose track of where you are.
    ii. *Tip:* If you have a power drill available, you can use it to speed up the process (see the video below Figure 7 to find out how).
    iii. *Tip:* To keep the dangling wire out of your way as you wind the coil form, you can push the dangling wire into the coil form's inner tube.
d. When you have completed approximately 1,500 wraps of wire, leave about 30 cm of wire dangling off the coil. Then use scissors to cut the other end of the wire. Use tape to secure the wire in place so it does not unwind.

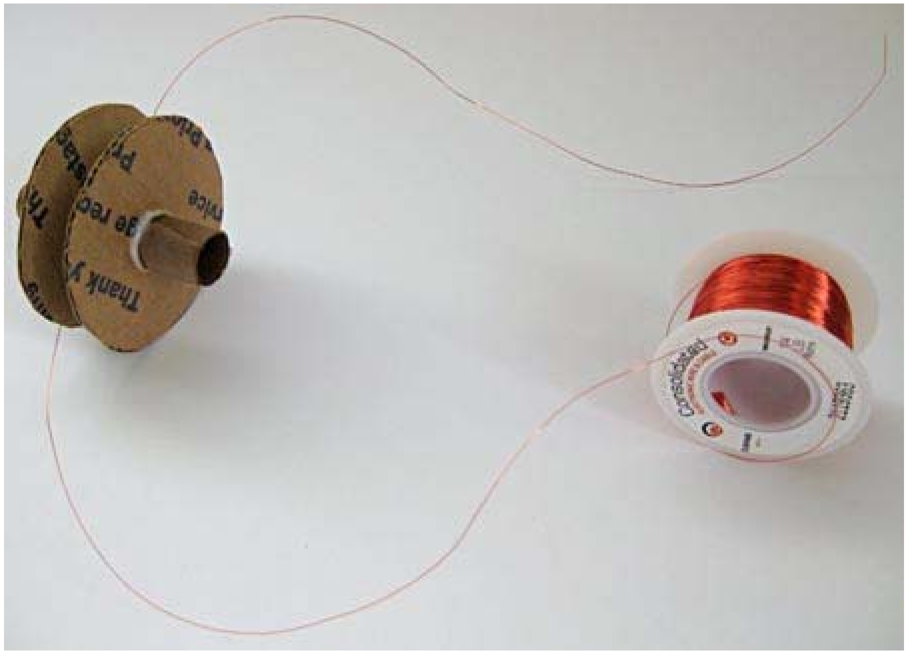


Figure 6. Tape the magnet wire to the inside of one of the cardboard pieces so that there is about 30 cm of wire dangling off of your coil form.

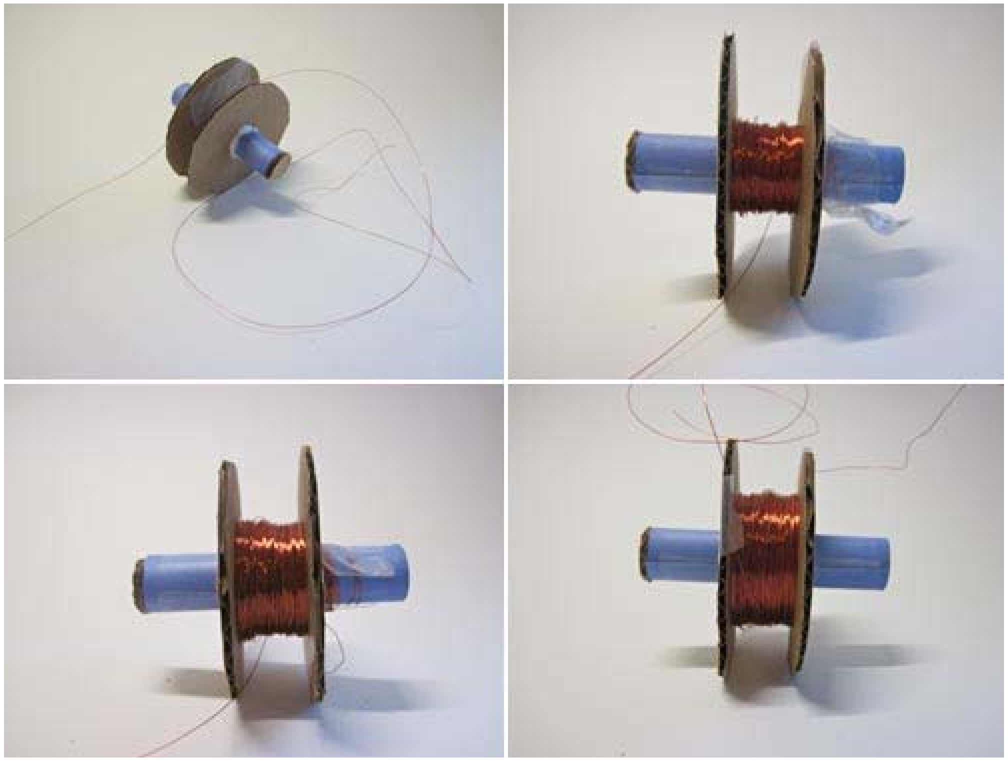


Figure 7. Carefully and tightly wrap the wire around the coil form for a total of approximately 1,500 wraps. This figure shows (top left) zero wraps, (top right) 500 wraps, (bottom left) 1,000 wraps, (bottom right) 1,500 wraps.

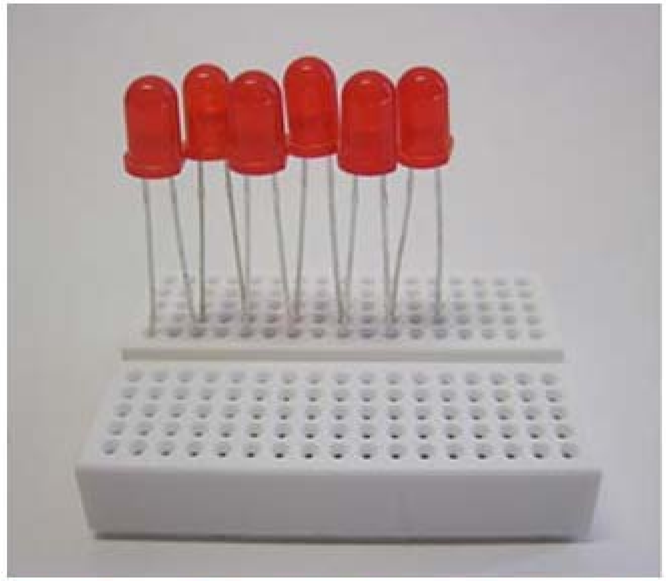
If you have one available, you can use a power drill to speed up the coil-winding process. You should ask an adult for help with this step.
https://www.youtube.com/watch?v=-Xl63aqWaTk (https://www.youtube.com/watch?v=-Xl63aqWaTk)

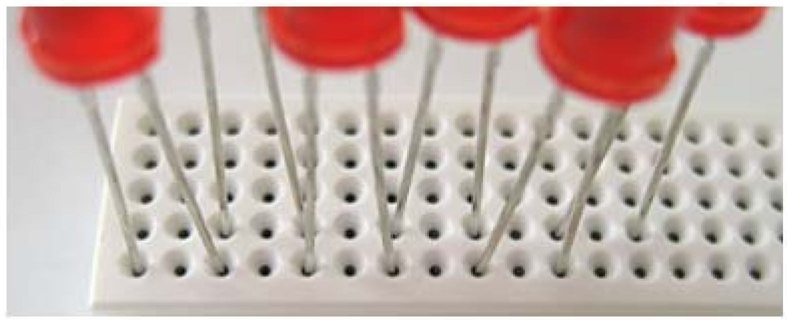
5. Finally, use your square of sandpaper to strip the enamel insulation off of roughly 3 cm segments at the end of both wires that are sticking out of your coil.
    a. If you do not know how to do this, refer to the Science Buddies Wire Stripping Tutorial. (http://youtu.be/Pd5Q-XDmvys)

Testing Your Generator

1. Set up your breadboard and LEDs.
    a. You will use a *solderless breadboard* to easily connect multiple LEDs. You can learn how to use a breadboard in the Science Buddies reference How to Use a Breadboard (http://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-breadboard). The LEDs have metal wires sticking out of them called *leads* (pronounced "leeds"). These leads can be easily inserted into and removed from tiny holes on the breadboard.

b. Insert six LEDs into the breadboard in a staggered row, as shown in Figure 8. *Important*: LEDs have two leads, one longer and one shorter. They represent the *positive* and *negative* sides of the LED, respectively. In order for multiple LEDs to be connected in a row (also called *in series*), the negative lead of one LED must be connected to the positive end of the next LED. Make sure that all of your *longer* (positive) LED leads are positioned on the *left*, and all of your *shorter* (negative) LED leads are positioned on the *right* or your experiment will not work properly.
    i. It may help to think about the LEDs like a chain of people holding hands. If all the people are facing the same direction, one person's right hand is holding the next person's left hand, and that person's right hand is holding the next person's left hand, and so on.
c. See the Technical Note, below, for additional information about LEDs and breadboards (you do not need to understand that information to complete this science project).





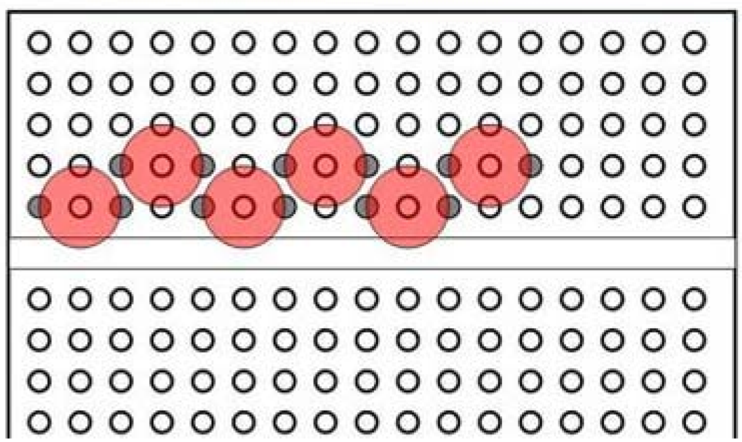


Figure 8. Arrange six LEDs in a staggered row on the breadboard, as shown here. (Top) A photograph of the actual breadboard. (Middle) A zoomed-in photo of the LED leads pressed into the breadboard holes. (Bottom) A top-down diagram of the breadboard showing the LED lights (red circles) and the holes to place the LED leads into (the small, solid gray circles). Remember to make sure all the *longer* LED leads are facing left, and all the *shorter* LED leads are facing right.

Technical Note: More about Breadboards and LEDs

This information is not essential to complete the science project; it is just provided for students who are interested in learning more.

LED stands for *light-emitting diode*. A *diode* is like a one-way door for electricity—it only lets electrical current flow through in one direction. "Light-emitting" diode means that LEDs will light up when electrical current flows through them. Since LEDs act like one-way doors, that is why you must make sure all the LEDs are facing in the same direction when you connect them. Otherwise they would prevent electrical current from flowing in *either* direction, and would never light up. This is easy to see if you draw a *circuit diagram* for the LEDs. In circuit diagrams, LEDs are represented by triangle symbols that show the direction electricity can flow, like in Figure 9:

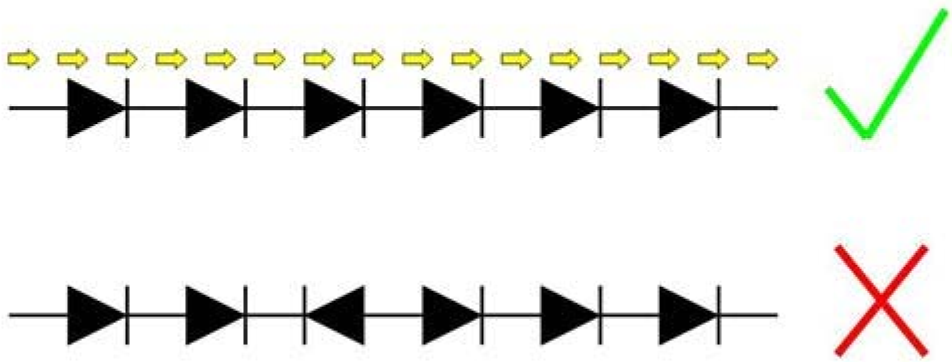


Figure 9. The triangle symbol with a line at the tip represents a single LED. When multiple LEDs are all connected facing the same direction, electrical current can flow through them. If just one LED is placed backwards, then electrical current cannot flow at all.

Solderless breadboards provide a convenient way to quickly connect or remove electronic components in a circuit. The small breadboard you are using in this science project has 17 rows of 10 holes each. Each row is split in half into five columns. Each half-row of five holes is *electrically connected* inside the breadboard. This is what allows you to connect the LEDs together, even though their leads are not touching. Figure 10 highlights each set of connected holes with yellow rectangles:

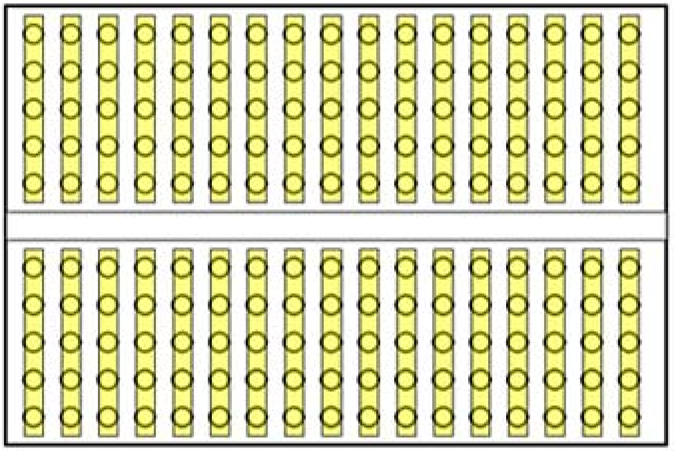


Figure 10. Each half-row of the breadboard, consisting of five holes, is electrically connected.

This means that it does not actually matter how exactly you put the LEDs into the breadboard, as long as the leads of each adjacent LED are connected to the same row on the breadboard (and the LEDs are all facing the same direction). The three configurations in Figure 11 below all do the same thing electrically:

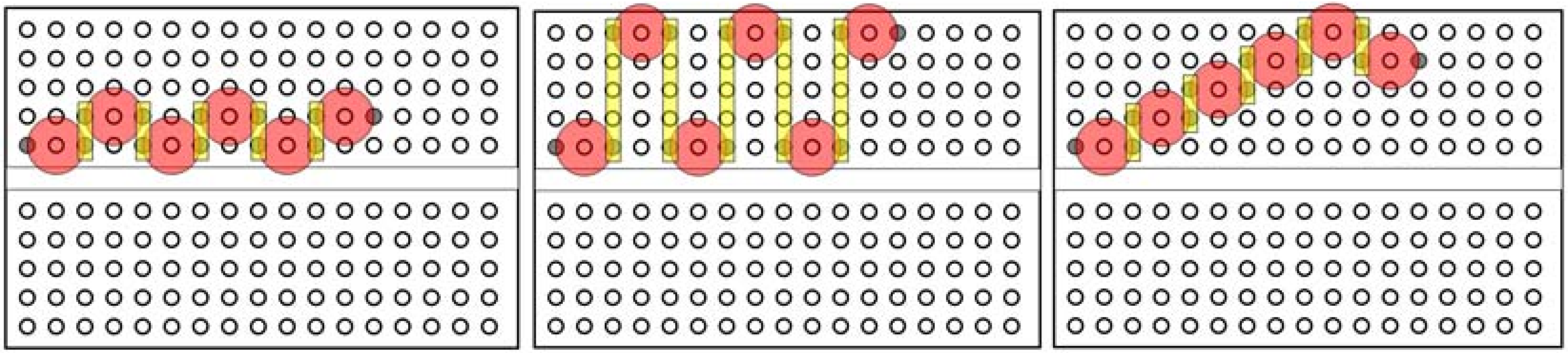


Figure 11. These three breadboard LED arrangements are all electrically equivalent. In each case, the leads of adjacent LEDs are connected through rows in the breadboard (highlighted by the yellow rectangles).

2. Create a data table in your lab notebook, like Table 1, below:

Number of LEDs	Number of Magnets Needed to Light Up
1	
2	
3	
4	
5	
6	

Table 1. Data table for recording how many magnets are needed to light up different numbers of LEDs.

3. Use your alligator clips to connect the first LED to your coil form (which will function as a generator), as shown in Figure 12.
    a. With the breadboard facing you, as shown in Figure 12, clip the red alligator clip onto the left-hand (longer) lead of the first LED. Clip the black alligator clip onto the right-hand (shorter) lead of the first LED *or* the left-hand (longer) lead of the second LED.
        i. Remember that the right-hand lead of the first LED and the left-hand lead of the second LED are electrically connected by the breadboard, so you can attach the alligator clip to either one.
    b. **Important**: Make sure that the red and black alligator clips *do not touch each other*. This will create a *short circuit* and will prevent your LED from lighting up.
    c. Clip the other end of each alligator clip onto one end of the wire from your coil. Be sure to clip on to the parts of the wire where you sanded off insulation.

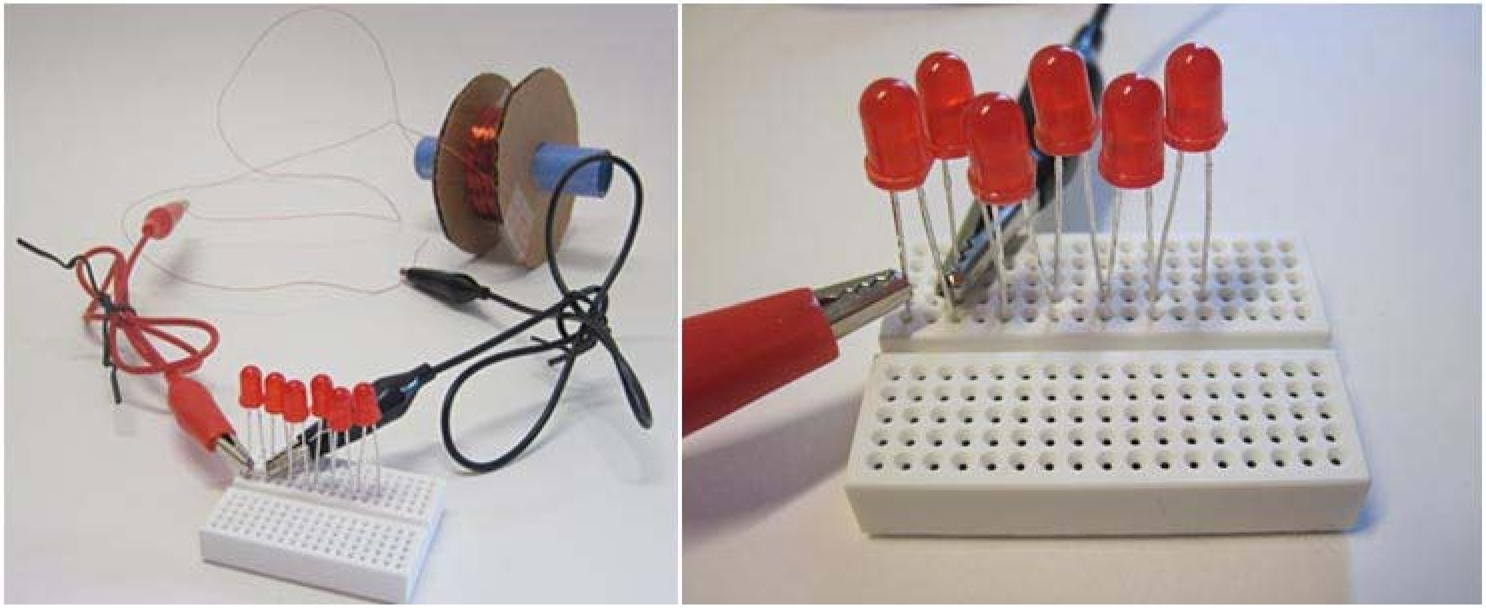


Figure 12. Connect the first LED to your generator coil with alligator clips, as shown here.

4. Now, you are finally ready to test your generator.
    a. Take your entire stack of six neodymium magnets and drop them inside the card stock tube of your generator. **Important**: Remember to follow all the safety rules listed above for neodymium magnets.
    b. Cover the ends of your generator with your thumb and fingers so the magnets do not fall out, and quickly shake it back and forth (but be careful not to shake loose the wires or breadboard attached to it!). Try to shake your generator at a consistent speed for all of your trials.
    c. Does the LED light up? You should see the LED flicker as you shake the magnets inside the generator.
    d. If the LED does not light up at all, look at the Help tab (http://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p009/energy-power/human-powered-energy#help) for troubleshooting tips.

Technical Note

The LED flickers because your generator creates *alternating current* (AC). This means that the electrical current alternates between positive and negative as you shake the generator. Since current can only flow through LEDs in one direction, the LED will only light up half of the time, and appears to flicker. Lighting up the LED continuously would require additional circuitry to make *direct current* (DC).

5. Determine how many magnets are required to light one LED.
    a. Now, take the magnets out of your generator and carefully remove one magnet from the stack of six. Set it aside, away from the other magnets.
    b. Put the stack of five magnets back inside your generator and shake it again. Does the LED still light up?

c. Keep removing magnets until the LED no longer lights up. What is the *minimum* number of magnets required to light a single LED? Enter your result in the data table in your lab notebook.

6. Determine how many magnets are required to light two LEDs.
    a. Move the black alligator clip from the short lead of the first LED (or the long lead of the second LED) to the short lead of the second LED (or the long lead of the third LED), as shown in Figure 13. Leave the red alligator clip in place.
    b. Start over with all six magnets. Remove one magnet at a time, and test your generator until the LEDs no longer light up. Record the minimum number of magnets required to light two LEDs in your data table.

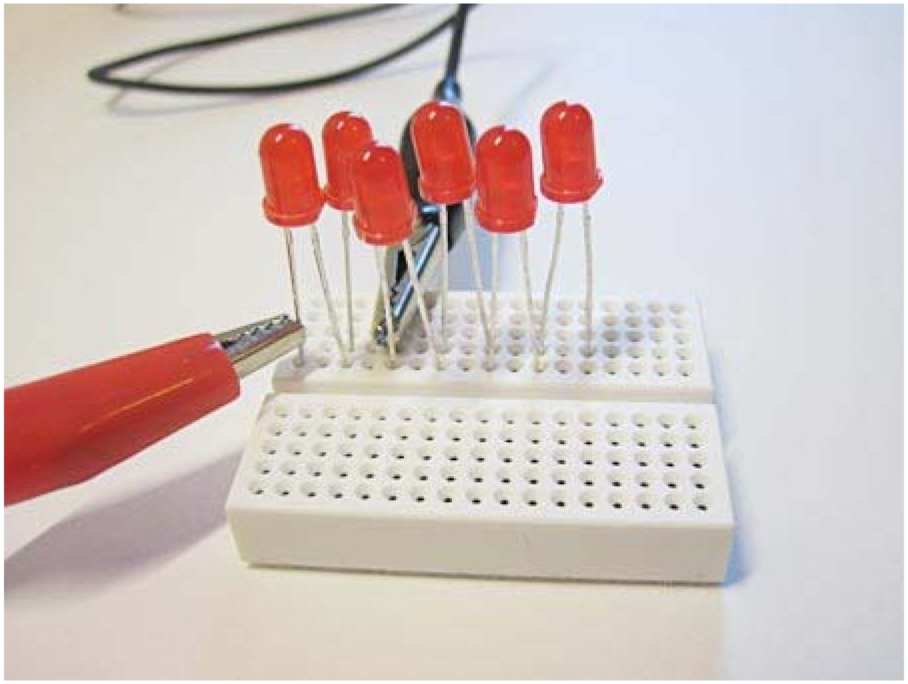


Figure 13. In order to test two LEDs, leave the red alligator clip in place. Move the black alligator clip to the shorter (right-hand) lead of the second LED.

7. Repeat step 6 for three, four, five, and six LEDs.
    a. Each time, move the black alligator clip to the shorter (right-hand) lead of the next LED (or the longer, left-hand lead of the LED after that), as shown in Figure 14.
    b. Each time, start over with all six magnets, and remove one magnet at a time until the LEDs no longer light up. Record the minimum required number of magnets in your data table.
    c. *Note*: If you are having trouble getting the LEDs to light up, try *flipping your magnets around*. Sometimes when you wind a 1,500-wrap coil by hand, it can become a bit lopsided, and the amount of electricity that is generated will not be perfectly symmetric as you shake it back and forth. As a result, your magnets might work better facing in one direction than in the other. So, if the LEDs do not light up at all, always flip the magnets around and try again before you record results in your data table.

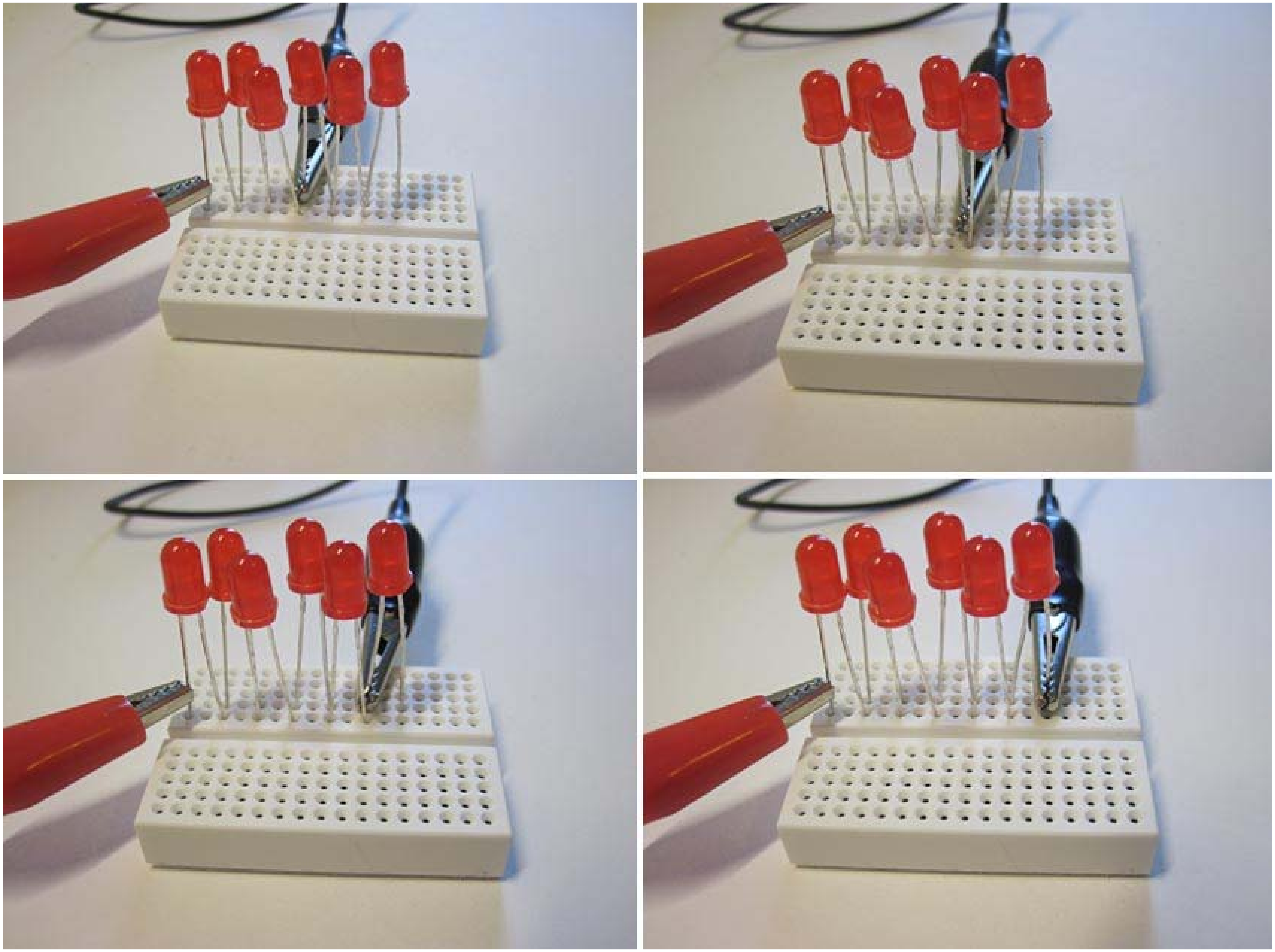


Figure 14. The black alligator clip connected to the third, fourth, fifth, and sixth LEDs (top left, top right, bottom left, and bottom right, respectively).

8. When you have finished testing all six LEDs, analyze your results.
    a. Make a graph of the data from your data table, putting the number of LEDs you tried to light up on the x-axis and the number of magnets that were required to light up the LEDs on the y-axis.
    b. Do you see a relationship between the number of magnets and the number of LEDs that you can light up? What was your hypothesis about this relationship?
    c. How can you explain your results? Does adding more magnets make a stronger magnetic field? Is there a relationship between the strength of a magnetic field and the amount of electricity induced in the coil?

Frequently Asked Questions (FAQ)

FAQ for this Project Idea available online at https://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p009/energy-power/human-powered-energy#help (http://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p009/energy-power/human-powered-energy#help).