Overview:

Students construct a simple electric generator using magnets and copper wire to understand how electricity works.

Objectives:

The student will:

- compare how hand tools and electrically-powered tools use energy and do work;
- make a simple electric generator using magnets and copper wire; and
- explain how a simple generator makes electricity.

Targeted Alaska Grade Level Expectations:

Science

[5] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[5] SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by classifying the changes (i.e., heat, light, sound, and motion) that electrical energy undergoes in common household appliances (i.e., toaster, blender, radio, light bulb, heater).

Vocabulary:

closed circuit - an electric circuit through which current can flow in an uninterrupted path

electricity - the collection of physical effects related to the force and motion of electrically charged particles, typically electrons, through or across matter and space

electromagnetic - pertaining to or exhibiting magnetism produced by electric charge in motion

electromagnetic energy or electromagnetic radiation - Energy in the form of transverse magnetic and electric waves. In a vacuum, these waves travel at the speed of light (which is itself a form of electromagnetic radiation). The acceleration of electric charges (such as alternating current in a radio transmitter) gives rise to electromagnetic radiation. Other common examples of electromagnetic radiation are x-rays, microwaves, and radio waves. A single unit, or quantum, of electromagnetic radiation is called a photon. A Closer Look In the nineteenth century, physicists discovered that a changing electric field creates a magnetic field and vice versa. Thus a variation in an electric field (for example, the changing field created when a charged particle such as an electron moves up and down) will generate a magnetic field, which in turn induces an electric field. Equations formulated by James Clerk Maxwell predicted that these fields could potentially reinforce each other, creating an electromagnetic ripple that propagates through space. In fact, visible light and all other forms of electromagnetic radiation consist exactly of such waves of mutually reinforcing electric and magnetic fields, traveling at the speed of light. The frequency of the radiation determines how it interacts with charged particles, especially with the electrons of atoms, which absorb and reemit the radiation. The energy of the electromagnetic radiation is proportional to its frequency: the greater the frequency of the waves, the greater their energy. Electromagnetic radiation can also be conceived of as streams of particles known as photons. The photon is the quantum (the smallest possible unit) of electromagnetic radiation. In quantum mechanics, all phenomena in which charged particles interact with one another, as in the binding of protons and electrons in an atom or the formation of chemical bonds between atoms in a molecule, can be understood as an exchange of photons by the charged particles.

energy - the ability to do work, such as the ability to move an object by pushing on it. Energy can exist in many forms, including motion, heat, and electricity.

generator - a device that converts mechanical energy to electrical energy by spinning a coil of copper wire inside a magnet (or by spinning a magnet inside a coil of copper wire). The larger the magnet and coil of copper wire, the more electricity is made and the more work can be done.

magnet - a material or object that produces a magnetic field. Lodestones are natural magnets, though many materials, especially metals, can be made into magnets by exposing them to a magnetic field.

magnetic field - a field of force associated with changing electric fields, as when electric charges are in motion. Magnetic fields exert deflective forces on moving electric charges. Most magnets have magnetic fields as a result of the spinning motion of the electrons orbiting the atoms of which they are composed; electromagnets create such fields from electric current moving through coils. Large objects, such as the earth, other planets, and stars, also produce magnetic fields.

Whole Picture:

There are many forms of energy, such as thermal or heat energy (fire), chemical (glucose in the body), electrical (generator), mechanical (drill press), electrochemical (battery), electromagnetic (radio or light waves), sound (loud speaker), and nuclear (fission). Energy can generally be classified as potential (stored) or kinetic (doing work). The word kinetic comes from the Greek word kīnētikós, which means to move.

Electricity, or electrical energy, is a secondary type of energy. Other primary forms of energy, such as coal, hydropower, or mechanical energy, are required to generate electricity. Electrical energy is important in many different areas of our lives. We use electricity to keep our food cold so it stays fresh, and we use it to heat our food when we cook. We use electrical tools to help us build our homes and fix things. Electrical energy also helps us keep our homes warm in winter and cool in summer. Electrical energy helps us see in the dark, watch a movie, listen to music, or play a video game. To do all these things with electricity, it is necessary to change electrical energy into other forms of energy such as heat, light, sound, or mechanical energy. Each tool or appliance we use has been designed to change electrical energy in a particular way.

Electricity is a form of energy caused by electrons moving from atom to atom. Atoms are made up of three subatomic particles; neutrons, protons and electrons. Protons carry a positive charge (+), electrons carry a negative charge (-) and neutrons are neutral and do not carry a charge. Protons and neutrons are held together very tightly but electrons can be moved between atoms. When the number of protons and electrons are equal the atom has a neutral charge. If an atom loses an electron it will have more protons (+) than electrons (-) and have a positive charge. If an atom gains an electron it has more electrons (-) than protons (+) and will have a negative charge. Electrons flow from negative (extra electrons) atoms to positive (electron deficient) atoms. This flow of electrons results in electrical energy.

Materials:

Choose one the following two for the activity demonstration:

- Electric drill and Hand-power drill, plus a 2 foot x 4 foot piece of wood (or other size piece of wood) or
- Hand mixer and electric mixer, plus two pints of whipping cream or heavy cream and two bowls

Each of the following:

- Lab materials
- Computer with Internet access
- Multimedia video: http://amasci.com/amateur/coilgen.html
- 1x2x5cm ceramic magnet (4 per group) (Edu. Inv M-700 or Radio Shack #64-1877, HFT, or CMS)
- #30 Magnet wire 200ft (1 per group) (Radio Shack 278-1345, or cheaper from other stores)
- Miniature Lamp, 1.5V 25mA (1 per group) (Radio Shack #272-1139, All. LP-3, or #48 lamp)
- Cardboard to make cardboard strip, 8cm x 30.4cm (1 per group, students may cut out)
- Large nail, 8cm long or more (1 per group)
- Knife or sandpaper to strip the wires (1 per group)
- Scissors (1 per group)
- Tape to hold wire down
- Optional: Hand drill or electric drill to spin it (hand drill is best)

NOTE: If you use different parts, it won't work. For suggestions to order materials in bulk go to http://amasci.com/amateur/coilgen.html.

- STUDENT WORKSHEET: "Electrical Energy"
- STUDENT LAB: "Build an Ultra-simple Electric Generator"
- TEACHER INFORMATION SHEET: "The History of the 'Ultra-simple' Electric Generator"
- TEACHER INFORMATION SHEET: "Troubleshooting the Ultra-Simple Electric Generator"
- TEACHER INFORMATION SHEET: "Ultra-simple Electric Generator: How it Works"

Activity Preparation:

1. For the lesson demonstration described in Activity Procedure step 1, choose whether to demonstrate using the power/hand drill or the electric/hand mixer demonstration, depending on availability.
2. Prepare materials for the lab investigation. Plan to divide students into groups of three or four. Building a demonstration generator before the lesson is strongly recommended so that the teacher may help students build theirs more effectively and troubleshoot any problems.

Activity Procedure:

1. Choose one of the following demonstrations to begin the lesson:
    a. Power Drill/Hand Drill Demonstration: Use a muscle-powered hand drill to drill a hole in a 2 foot x 4 foot piece of wood. Then use the electrically powered drill to drill a hole.
    b. Electric Mixer/Hand mixer Demonstration: Pour a pint of cream into each bowl. Use one tool for each bowl to demonstrate how long it takes to whip cream using electricity versus muscle power. Have students take turns hand-whipping the cream.

Critical Thinking Activity. ***The Five-Minute Paper Method.*** Give students one to five minutes to write down knowledge or ideas that attempt to answer the question: What is the difference between the power tool and the hand tool? In your answer, compare how each tool changes or uses energy to do work.

2. Ask students to think about the difference in the tools used in the demonstration. Consider the following questions as a class: How does each tool help do work? What is the energy source for each tool? Why does electricity make the work easier? How is the electricity transformed in the tool to make it useful? What is electricity?
3. Atoms are the basic building blocks of which all matter is made and are composed of protons, neutrons and electrons. Explain electricity is the movement of electrons, subatomic particles that orbit around the atom nucleus, from atom to atom. Some elements, like copper, make it easy for electrons to move from atom to atom. These elements are called conductors. When electrons to flow in a closed circle, or circuit, electrons move freely around this circuit and produce electricity. Electricity is a secondary source of energy: it needs to be generated by a primary source of energy, like coal, hydropower, or, in the case of the lab activity, muscle power. Explain students will produce electricity by building a simple generator using copper wire and magnets. Go to the website http://amasci.com/amateur/coilgen.html to view the video "Simple Generator" to show students a visual step-by-step demonstration of what they will be making. Hand out the STUDENT LAB: "Build an Ultra-simple Electric Generator." Break students into groups of three of four to complete the lab activity.
4. After each group has completed building the generators, invite each group to present their generator to the class. Draw from the TEACHER INFORMATION SHEET: "Ultra-simple Electric Generator: How it Works" to lead a discussion or explain how the generator works.
5. To wrap-up the lesson, pass out the STUDENT WORKSHEET: "Electrical Energy" and ask students to complete the worksheet.

Extension Ideas:

1. Take apart an old appliance, such as a blender, and compare the appliance motor with the simple generator students built. What are the similarities and differences? What metal is used for the motor? Can you find a magnet and coiled wires? How is electricity changed to do useful work?
2. Investigate how electricity is produced in your community.
3. Extension to "Build an Ultra-simple Electric Generator": Feel the Electrons
    a. After building and testing the ultra-simple electric generator, disconnect one wire from the light bulb. Spin the magnet. While still spinning the magnet, have another person touch the wires together so the bulb lights up again. Is the nail still as easy to spin? Keep spinning the magnet while the other person connects and disconnects the bulb. Do you feel any differences in how hard you must spin the nail? Also try spinning the magnets while the other person connects the generator wires directly together (with no bulb connected.)

       What's happening? When you crank the generator and make the light bulb turn on, you are working against electrical friction to create the heat and light. You can feel the work you perform, because whenever you connect the bulb, it suddenly gets harder to crank the generator. When you disconnect the bulb, it gets easier.

       Think of it like this. If you rub your hands together lightly, the skin stays cool, but if you rub your hands together hard, your skin gets hot. It takes more effort to rub skin hard so that it heats up; it takes work. And in a similar way, it's hard to heat the light bulb filament; it takes work. You twist the generator shaft, the generator pushes the wire's charge through the tiny filament, and if you don't keep spinning the magnet, the magnet will be slowed quickly.

       When your hand spins the magnet, you can feel the extra work it takes to light the bulb. This happens because your hand is connected to the flowing charge in the bulb, and when you push on it, you can feel it push back on you! How is your hand connected to the flowing charges? Your hand twists the nail, the nail spins the magnet, the magnet pushes the invisible magnetic fields, the fields push the movable charges, the charges flow slowly through the light bulb filament, and the tiny filament causes friction against the flow of charge and heats up. But then the reverse happens! The charge can't move much because of the tiny filament, so it resists the pressure from the magnetic fields, which in turn resist the pressure from the magnet, which resists the twisting pressure from the nail, which resists the twisting pressure from your fingers. So, in a very real way, you can feel the electrons in the light bulb filament. When you push them, you can feel their reluctance to move through the narrow filament!

    b. Try changing the magnets' position. Remove the magnets, then tape them around the nail so that the two stacks are clinging side by side, rather than stacked up in a line. Spin the magnets. Does the light bulb still light up? No. This happens because The N pole of one magnet stack is very close to the S pole of the other, and vice versa. The magnetic field is now stretching between the two stacks of magnets, and isn't spreading outward. Most of the field is trapped between the neighboring opposite poles, so the field doesn't extend out through the coil. When magnets are side by side like this, they form one larger but weak magnet. On the other hand, when you make a single stack of magnets instead, the field extends outwards for many inches. The stacked magnets form a larger but very strong magnet. If you spin the single magnet stack, the field cuts through the wires and pumps their electrons into motion.

    c. Measure the voltage and current. If you can get a Digital Voltmeter or DVM, you can make some measurements. (Once you can see some numbers, you can perform some professional science experiments. This is great for science fair projects.) Spin the magnets to light up the bulb, then connect the meter leads across the light bulb connections. Set the meter for AC volts. Spin the magnets and see just how high a voltage your generator produces.

       How high can you make the voltage just by using fingers? Or using a hand drill? Try spinning the magnets just fast enough to barely light the bulb in a dark room. How small a voltage is needed?

Also try disconnecting the light bulb, then measure the AC voltage across the two ends of the coil. Can you tell if it's still the same as when the bulb was connected? Hint: to spin the magnets at a constant rate, use an electric drill with a fully-charged battery. Or perhaps hook the nail to an electric motor and connect the motor to a DC power supply with settable voltage.

NOTE: The light bulb has around 50 ohms resistance. Also, 250ft of #30 wire has around 21 Ohms resistance. Because of the wire resistance, the generator can only create around 60 milliamps current at most (0.06 amperes.) If you wind extra #30 wire onto the generator, it will increase the maximum voltage, and maximum power. But since this adds more resistance it WON'T increase the maximum possible current. To increase the maximum possible current, either spin the magnets much faster, replace the #30 wire with thicker wire, or use a stronger type of magnet material.

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d. There is a simple way to convert your generator into a motor. It involves using paint or tape to insulate a spot on one side of the nail, then using a 6V battery and using the generator's wires, touching the nail to form a switch. The rotating magnets turn the nail, which turns the coil on and off at just the right times. Can you discover the trick?

Answers:

STUDENT WORKSHEET: "Electrical Energy"

1. C. moving electrons
2. D. secondary
3. Answers will vary, but in their own words students should say that a moving magnetic field causes an electrical current in a closed circuit. Another example of a correct answer: The force of human muscles got the electrons moving in the magnets, generating electricity.
4. Answers will vary, but students should include two: more copper coils, stronger magnets, faster rotation, or larger copper coils.

NAME: ______________________________

ELECTRICAL ENERGY

Directions: Answer the questions below.

1. What is electricity?

   A. Closed circuit

   B. Copper wire

   C. Moving electrons

   D. Moving water

2. Humans produce electrical energy from other forms of energy, like coal or hydropower. Electrical energy is a ____________________ source of energy.

   A. made from lightning

   B. primary

   C. unnecessary

   D. secondary

3. Why did you need to spin the magnets in your simple generator to make the light shine?

   ____

   ____

   ____

   ____

4. What are two ways to make the simple generator move more electrons and make the light shine brighter?

   A. ____

   B. ____

NAME: ______________________________

BUILD AN ULTRA-SIMPLE ELECTRIC GENERATOR

Note: The generator made from these instructions produces Alternating Current, not Direct Current. The output voltage is about 2 volts maximum, so there is no electric shock hazard at all.

Investigation:

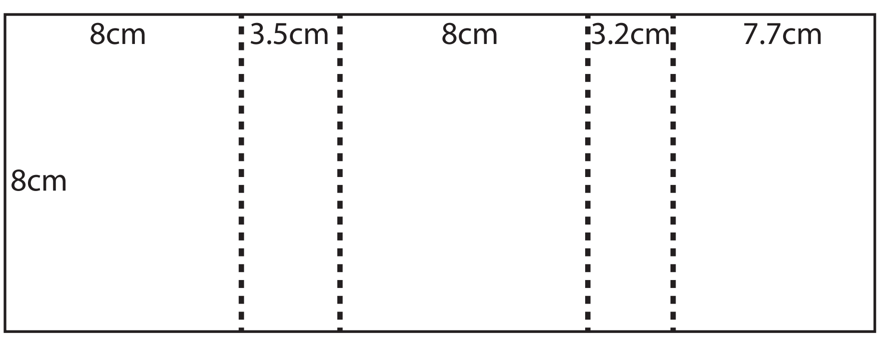
Materials:

- 1x2x5cm ceramic magnet (4 per group) (Educational Innovations M-700 or Radio Shack #64-1877, HFT, or CMS)
- #30 Magnet wire 200ft (1 per group) (Radio Shack 278-1345, or cheaper from other stores)
- Miniature Lamp, 1.5V 25mA (1 per group) (Radio Shack #272-1139 $1.29, All. LP-3, or #48 lamp)
- Cardboard to make cardboard strip, 8cm x 30.4cm (1 per group, students may cut out)
- Large nail, 8cm long or more (1 per group)
- Knife or sandpaper to strip the wires (1 per group)
- Scissors (1 per group)
- Tape to hold wire down
- Optional: Hand drill or electric drill to spin it (hand drill is best)

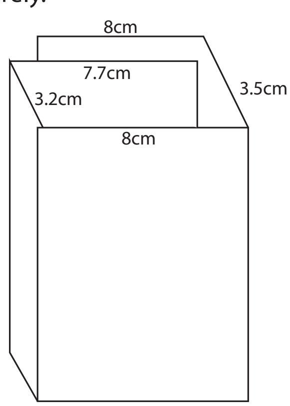
Note: Keep the magnets away from computers, disks, videotapes, color TV sets, and from wallets and purses containing credit cards.

Procedure:

1. This is an AC electric generator which lights up a tiny incandescent light bulb. The generator is made from a hollow-ended cardboard box with a nail through the center. The box has many turns of varnished thin copper wire wound around, with four large magnets clamped around the nail. When the nail and magnets are spun fast by hand, the little light bulb lights up dimly.
2. First make the hollow-ended box. Score the cardboard strip like so:



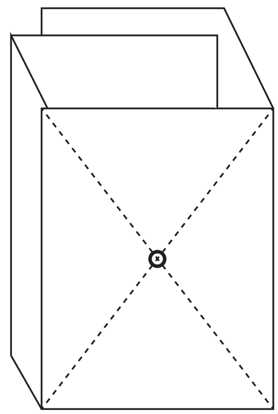
3. Fold it like this and tape it securely.



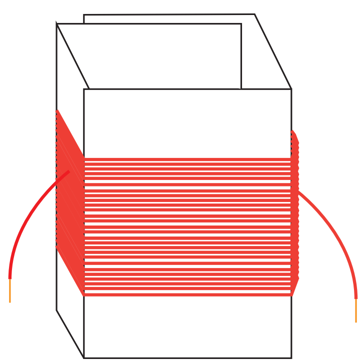
NAME: ______________________________

BUILD AN ULTRA-SIMPLE ELECTRIC GENERATOR

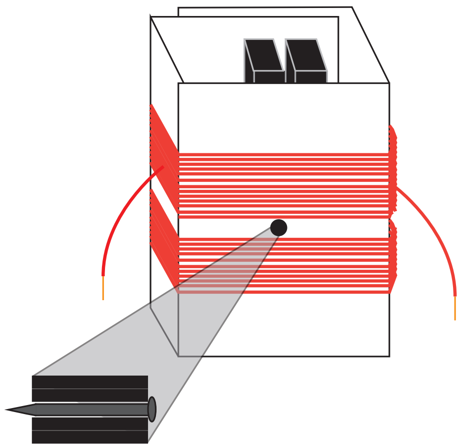
4. Use the nail to poke a hole perfectly straight through the center of the box, going through both sides and all three layers of cardboard. Then pull the nail out and use it to widen all the holes slightly, so when you put the nail back through, it will be a bit loose and able to spin. (Find the exact center by using a ruler to draw an "X" from the corners.)



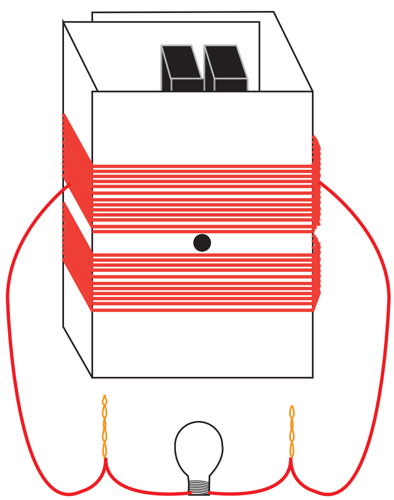
5. At this point you should let your four magnets clamp themselves around the nail, and give it a spin. This guarantees the box is large enough. The nail and magnets should spin freely. The corners of the magnets should NOT bump the inside of the box as they spin.
6. Pick the spool of number-30 varnished wire from the kit of spools. This is the thinnest. Tape one end of the number-30 magnet wire to the side of the box, then wind all of the wire onto the box as shown. It's okay to cover up the nail hole. Pull the taped end of the wire out, then tape down both of the wires so the coil doesn't unwind. You should have about 10cm of wire left sticking out.
7. Use sandpaper or the edge of a knife to scrape the thin plastic coating off 2cm of the wire ends. Remove every bit of red coating, so the wire ends are coppery.



8. Spread the wire away from the nail hole and tape it in place. Stick the nail back through the holes and make sure it can spin. Take your four magnets, stick them face to face in two pairs. Then stick the two pairs inside the box and on either side of the nail so they grab the nail. Push them around until they are somewhat balanced and even, then spin the nail and see if they turn freely. If you wish, you can push 2cm squares of cardboard between the magnets to straighten them. If you wish, tape the magnets so they don't move around on the nail.



9. Before twisting the wires together to the bulb, make sure that each end of the generator's wires are totally cleared of red plastic coating. If there is a bit of plastic left, it might act as an insulator, which turns off your light bulb circuit.
10. Twist the scraped end of each generator wire securely around the silver tip of each wire from the small light bulb. (If necessary, use a knife to strip more plastic from the ends of the light bulb wires.) One generator wire goes to one light bulb wire, the other generator wire goes to the other light bulb wire, and the two twisted wire connections should not touch together. In the twisted wires, metal must touch metal with no plastic in between.



Test it. Spin the magnet REALLY fast and the bulb will light dimly. If it doesn't work, try spinning it in a dark room so you don't miss the dim glow. If needed, adjust the position of the magnets so they don't hit or scrape the cardboard. It has to spin fast, and if the magnets whack the cardboard and slow down, you won't see any light. (If it doesn't work, ask the teacher for help troubleshooting.)

12. Once you get it to work, try clamping the point of the nail into the chuck of a hand-crank drill. Spin the magnets fast with the drill and the bulb will light brightly. Don't go too fast or you'll burn out the bulb, or maybe fling magnets all over the room. You can try this with an electric drill as well, although electric drills don't spin as fast.

Credit: This activity was created by William Beaty, a research engineer at the University of Washington, and is available online at http://amasci.com/amateur/coilgen.html.

ULTRA-SIMPLE ELECTRIC GENERATOR: HOW IT WORKS

All metals contain a movable substance called "electric charge." Even uncharged wires are full of charge! After all, the atoms of the metal are made half of positive protons and half of negative electrons. Metals are special because their electrons don't stay connected to the metal atoms; instead they fly around inside the metal and form a type of electric "liquid" inside the wires. All wires are full of electric fluid. Modern scientists call this the "electron sea" or "electron gas." The fluid charge is movable, and this lets metals be electric conductors. The movable charge-stuff is not invisible, it actually gives metals their silvery shine. The electron gas is kind of like a silvery fluid.

When a circle of wire surrounds a magnetic field, and the magnetic field then changes, a circular "pressure" called voltage appears. The faster the magnetic field changes, the larger the voltage becomes. This circular voltage tries to force the movable charges in the wire to rotate around the circle. In other words, moving magnets cause changing magnetic fields, which try to create electric currents in closed circles of wire. A moving magnet causes a pumping action. If the circuit is not complete, if there is a break, then the pumping force will cause no charge flow. Instead, a voltage difference will appear at the ends of the wires. But if the circuit is "complete" or "closed," then the magnet's pumping action can force the electrons of the coil to begin flowing. A moving magnet can create an electric current in a closed circuit. The effect is called Electromagnetic Induction. This is a basic law of physics, and it is used by all coil/magnet electric generators.

Generators don't have just one circle of wire. Suppose that many circles surround the moving magnet. Suppose that all the circles are connected in series to form a coil. The small voltages from all the circles will add together to give much larger voltage. A coil with 100 turns will have a hundred times more voltage than a one-turn coil.

If we connect the ends of the coil together, then whenever the magnet moves, the metal's charges will move and a large electric current will appear in the coil. What if we instead connect a light bulb between the ends of the coil? A light bulb is really just a piece of wire. The charges of the light bulb's filament will be pushed along. When the charges within the copper wire pass into the thin light bulb filament, their speed greatly increases. When the charges leave the filament and move back into the larger copper wire, they slow down again. Inside the narrow filament, the fast-moving charges heat the metal by a sort of electrical "friction." The metal filament gets so hot that it glows. The moving charges also heat the wires of the generator a bit, but since the generator wires are so much thicker, almost all of the heating takes place in the light bulb filament.

So, just connect a light bulb to a coil of wire, place a short powerful magnet in the coil, then spin the magnet fast. The faster you spin the magnet, the higher the voltage pump-force becomes, and the brighter the light bulb lights up. The more powerful the magnet, the higher the voltage and the brighter the bulb. And the more circles of wire in the coil, the higher the voltage and the brighter the bulb.

THE HISTORY OF THE ULTRA-SIMPLE ELECTRIC GENERATOR

While running the tech shop at the Museum of Science in Boston, William Beaty was working on new ideas for exhibits for the Electricity Hall in 1988. He knew that the Exploratorium had an electric generator exhibit where the museum visitor would yank a plastic-embedded coil plate through a row of huge magnets (magnetron horn-magnets from a military radar). Doing so would light up a small bulb. He knew that there had to be a way to use more common magnets. So he stacked up a pile of 3" loudspeaker magnets (those black donut things) and waved it past various coils. Finally he wound about five pounds of #26 wire around a ring of nails pounded into a board, hooked up a #49 light bulb, then moved the stack of speaker magnets in and out. This easily lit up the bulb.

Around 1994 he was thinking about the ultra-simple electric motor, which later became known on the Internet as the "Beakman Motor." Wouldn't it be cool if kids could also make an electric generator that simple? But it should be possible with parts from a Radio Shack store, since Radio Shack had the special light bulb as well as magnets and spools of electromagnet wire. After a few hours of experimenting, he found that he could just barely light up the 20 milliamps bulb by using a single spool of #30 wire from radio shack. But the wire had to be VERY close to a fast spinning magnet, and the magnet had to be composed of four powerful ceramic magnets in a stack.

To impress all the Physics Teachers, he tried to make the parts be easily available, and the cost as low as possible. To make a popular project, he made sure no tools were needed except scissors. He refused to use ball bearings or plastic parts. So he made his own cardboard box for the coil, and used a nail for the spinning shaft. To avoid extra parts, the nail is just clamped by the powerful magnets.

TROUBLESHOOTING THE ULTRA-SIMPLE ELECTRIC GENERATOR

DON'T USE DIFFERENT PARTS. If the light bulb won't light, usually it's becaused different parts were used. Follwo instructions. If you changed the magnets, it won't work. So don't use different magnets. If you used a different bulb, it won't work. Use the parts in the list, don't make changes. If you're not using #30 varnish-coated wire, then it won't work. So don't use different wire. Don't use different parts. Before testing anything else, ask yourself if you used the parts in the parts list? If you used different parts, the generator will fail. Notice: it's very important that you use the parts listed, and don't use substitutes.

SPIN IT FAST, IN THE DARK. Sometimes your generator is working fine, but you're not spinning it fast enough. Or perhaps the dim glow of the light bulb is being missed in a brightly lit room. So, go into semi-darkness. Then spin the thing REALLY FAST. Try cranking it with an old-fashioned drill. (Electric drills don't turn very fast.) Or try gluing a tiny wheel to the nail, then rub the wheel on the spinning tire of an upside-down bicycle (don't go too fast or the bulb will burn out.)

ADD LOTS MORE WIRE. If your coil has more than 250 turns, then the bulb glows much brighter. The Radio Shack wire is 200 feet long, which gives about 250 turns. If you could wind more turns on your coil, then your bulb would light up at lower magnet speed. Buy two kits of wire from Radio Shack, then use both spools of #30. Scrape every bit of the red plastic coating off all the wire ends. Then twist the end of the new spool to the end of the old one. This creates a single longer wire. Be sure to wind the extra wire in the same direction as before. Better source of wire: buy a large "Solenoid" from a mail order company, then use Vice-grip pliers to pry open the metal bracket. The hole in the solenoid goes through a square steel plate, and if you pry the rest of the steel frame outwards, you can remove the square plate and take out the wire spool. Peel off the tape, and wind 600 turns on your generator. Try this one:

DON'T USE OTHER MAGNETS, use the large 2-inch rectangular magnets sold by Radio Shack, #64-1899. Or try Edu. Innovations, or CMS. They cost about $2 each, and have no holes through the center. Don't use the smaller 1 inch Radio Shack magnets. Most other magnets are way too weak and will not work unless you spin the magnets incredibly fast, at thousands of RPM (revolutions per minute.)

DON'T USE A DIFFERENT BULB. This generator cannot power a normal flashlight bulb; it needs the special 25-milliamp, 1.5-volt bulb sold by Radio Shack. Also try using a red LED. Don't use a normal flashlight bulb, since that kind of bulb requires way more energy before it starts to glow. If you simply cannot find the Radio Shack 25mA bulb, you can use a 1.5V 40mA bulb, but add twice as much magnet wire to your coil (buy two of those kits of magnet wire.) The generator needs more than 250 turns wrapped around it. Five hundred turns is better, that way you won't have to spin the magnets so fast.

STACK THE MAGNETS SO THEY STRONGLY ATTRACT. Make sure the four rectangle magnets are stacked to create two strong poles, otherwise the generator won't work. Do this: stack up all four magnets so their widest faces are clinging together. Then jam the nail through the crack in the middle of the stack. Then take this apart, and re-assemble it inside the generator in the same way.

CLEAN THE WIRE ENDS THOROUGHLY. If the generator refuses to work, inspect the spot where the wires twist together. The coil of wire has a very thin red plastic coating, and you must clean ALL of this coating off the last half-inch of the wire ends before twisting them to the light bulb wires. Also, the tips of the light bulb wires must be stripped clean of all plastic. The metal part of the light bulb wire must touch the metal of the coil If there is any plastic between the metal of the generator wire and the light bulb wire, the circuit will be "open" and no charge will flow.

Be sure to follow the instructions and diagrams. You MUST wind the coil so the coil goes across the side of the box that has the nail hole. If you wind it so no coil is crossing the nail-hole side of the box, then the magnetic fields won't cut across the wires, and no electric voltage will be created.

Also, don't wind the coil over the open end of the box, otherwise you won't be able to get your fingers inside to make changes to the magnet.

If you cannot spin the magnets fast enough with your fingers, try a "twist drill" or hand-crank drill. Clamp the nail in the end of the drill and spin the magnets as fast as you can. An electric drill may work too, but most electric drills don't move as fast as the hand-cranked type.

AC VOLTMETER. If you have an electronic voltmeter, set it to measure two volts AC, then connect it to the generator wires and spin the generator. The light bulb needs a bit more than 0.50 volts AC in order to light dimly. At 1.0V it lights brightly. If your generator's voltage is lower than 0.5V, you need to spin it much faster, or you need strong magnets, or you need to add lots more turns of wire.

DON'T SUBSTITUTE THE MAGNETS OR THE LIGHT BULB WITH A DIFFERENT TYPE. It needs strong magnets and a low-voltage, low-current incandescent bulb. If your generator doesn't work, check the parts again and make sure you have the right type of magnets and the right type of light bulb. Don't use fewer magnets. Weaker magnets may work in theory, but you won't be able to spin them fast enough by hand, and a high speed motor will be required in order to spin them. Don't use an LED. A red LED could work in theory, but you need at least 1-1/2 volts to barely light one up (the green or blue kind need even higher volts.) The light bulb is better because it lights up at less than 1/2 volt. (If you really must light up an LED, use the red kind, and also add about three more spools of #30 wire to your generator coil.)

Perhaps your luck is bad and you got a dead light bulb. To test it, get any new, fresh 1.5V battery (the size doesn't matter.) Take the bulb off the generator, then touch one wire form the bulb to the top of the battery and one wire to the bottom. The light bulb should light up brightly. If it stays dark, the bulb is bad.

The generator can be improved by using more turns of wire. You used only the spool of #30 wire. With more wire, the magnets don't have to spin as fast to light the bulb. Connect the thinnest of the remaining spools of wire to one end of the wire that's already wrapped, making sure to scrape the wire ends totally clean before twisting them together. Make sure to wind the extra wire in the same direction as the rest of the coil.

Or, if you want to light your light bulb REALLY bright, buy a second kit of wire, hook the second #30 spool to the coil you have already made, then wind all the wire onto the coil. Be sure to clean all the red plastic off the ends of the extra wire that you've added.