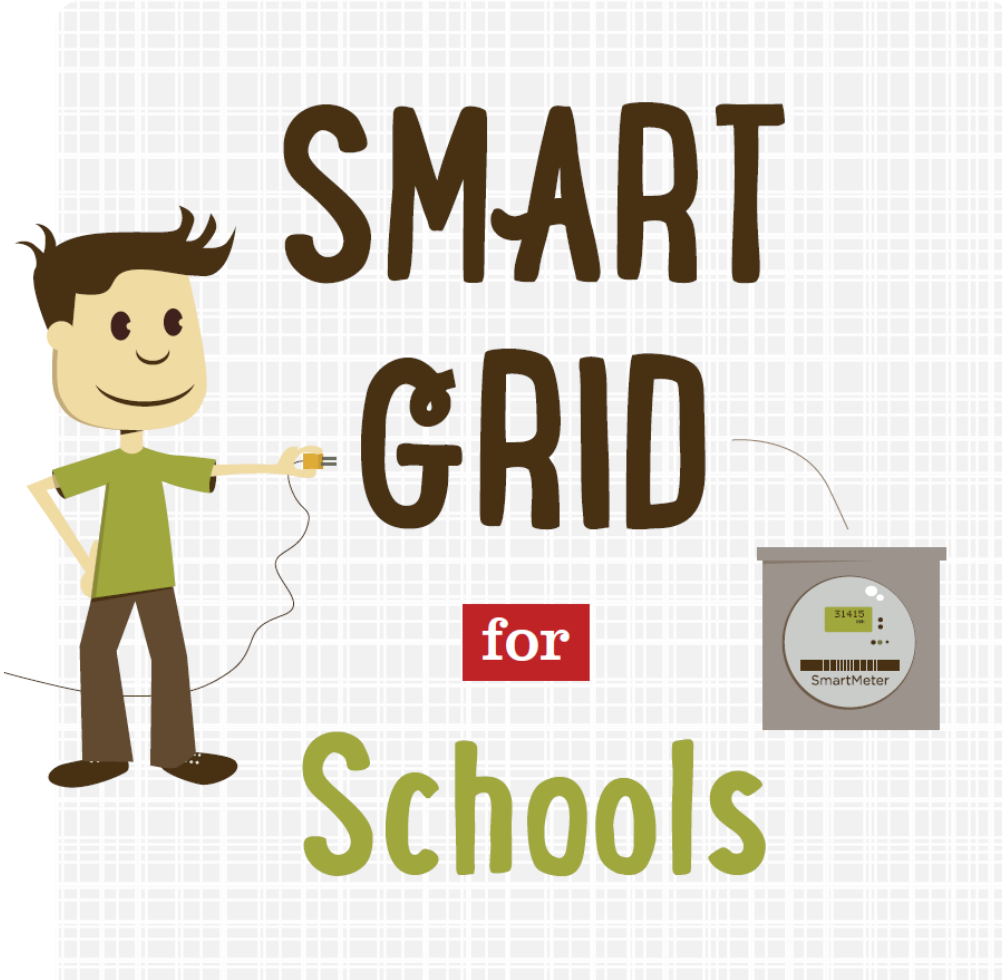


Construction Set Curriculum

Grades 8-12

Student Edition

Center for Mathematics Science and Technology

Center for Renewable Energy

Illinois State University

Normal, Illinois

SMART GRID for Schools

Construction Set Curriculum

Grades 8 - 12

Nearly everything done by humans requires some type of energy. Of course, manufacturing, transportation, and construction require energy, but also the “little things,” like heating your food and charging your cell phone. Energy allows things to be done. Imagine the changes necessary if gasoline was suddenly unavailable for your car, or electricity was shut off at your school. Modern society could not function without energy.

Nearly all work was accomplished entirely by muscle power until relatively recent times. The domestication of animals helped to make work easier and more efficient, but both humans and animals have limited power and get tired easily. Inventors have always been looking for ways to produce power that is reliable and inexpensive. At the end of the Roman era, by about 200 B.C., Europeans were using waterwheels to crush grain, saw wood, and do many more tasks. 1200 years later in 1000 A.D., the Dutch had harnessed the power of wind to do many of the same tasks as well as pump water out of manmade basins to expose land.

https://www.google.com/imgres?imgurl=https%3A%2F%2Fi.redd.it%2F7en51y8osrlz.jpg&imgrefurl=https%3A%2F%2Fwww.reddit.com%2Fr%2Fancientrome%2Fcomments%2F6zzw4v%2Fthe_norias_of_hama_tech_referenced_in_painting%2F&tbnid=cFD679meUV8DfM&vet=12ahUKEwjpnKP9r7vnAhVBYa0KHWLlCCAQMygJegQIARBR..i&docid=Yg5zCQjBvV2lmM&w=972&h=648&itg=1&q=roman%20water%20wheel&hl=en&ved=2ahUKEwjpnKP9r7vnAhVBYa0KHWLlCCAQMygJegQIARBR

Your Horsepower

When James Watt first invented the steam engine, he was naturally asked how much power it produced. Since everyone was familiar with horses, he came up the term "horsepower" and the formula to calculate it. He based his equation on measurements he took from an average draft horse.

How much horsepower can you produce? Lets find out.

Work

1. **Work** is **Force** X **Distance**. The force is how much weight you move and the distance is how far up it goes. Going horizontally does not count. You can run for miles on flat land and do no work. Not fair, is it?
2. Step on a scale and write down your weight it pounds. This is the ***Force.***
3. Go to a long straight set of stairs. Measure the riser (up) on one step in a staircase (in inches). Multiply by the number of steps to get the total ***Distance*** up. Divide total inches by 12 to get feet. Remember, the length does not matter, only the height.
4. Multiply the ***Force*** by the ***Distance*** to get the amount of ***Work*** done. It is measured in ***foot pounds***. You will see that lighter students do less work. Heavier students will do more work.

Power

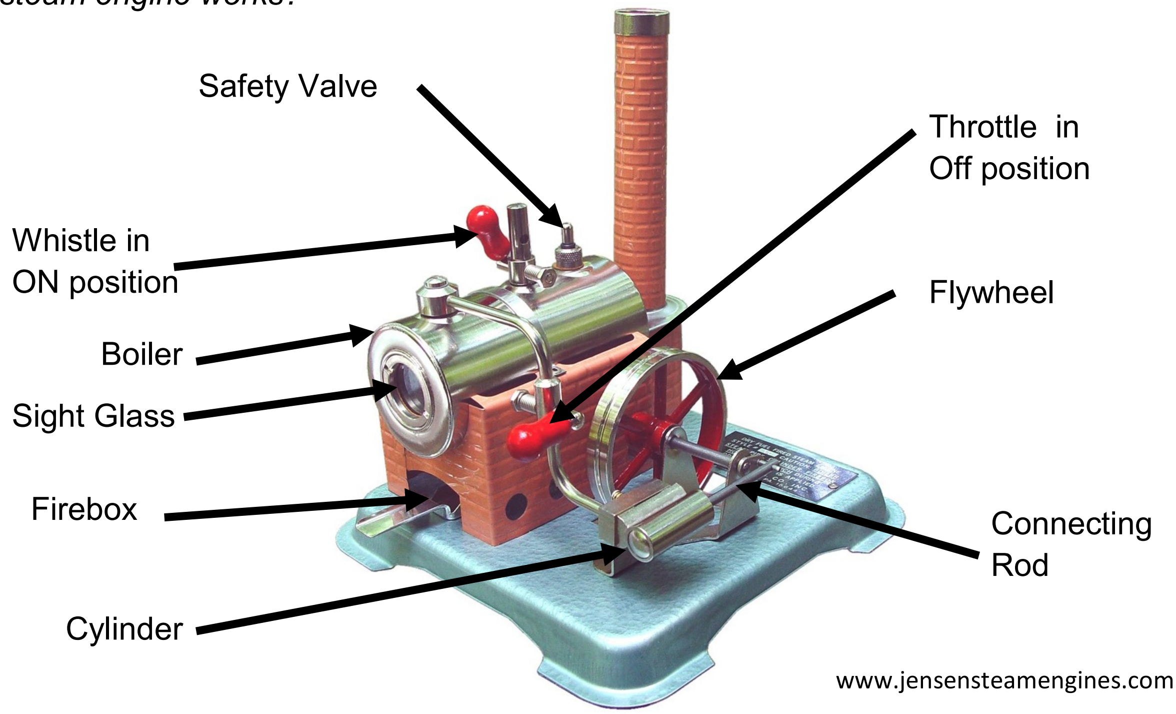
1. **Power** is **Work** divided by **Time.**
2. Have a friend time you as you run up the stairs as fast as possible. Write this down in seconds.
3. Divide ***Work*** by ***Time*** to get ***Power*** measured in ***foot pounds per second***
4. Divide ***Power*** by 550 to get ***horsepower***. 1 hp = 550 ft-lbs / second
5. Multiply ***horsepower*** by 746 to get ***watts***. 1 hp = 746 Watts

   It is very rare for a human to produce over 1 horsepower for more than a few seconds.
6. How do you compare? How long can you produce that much power?

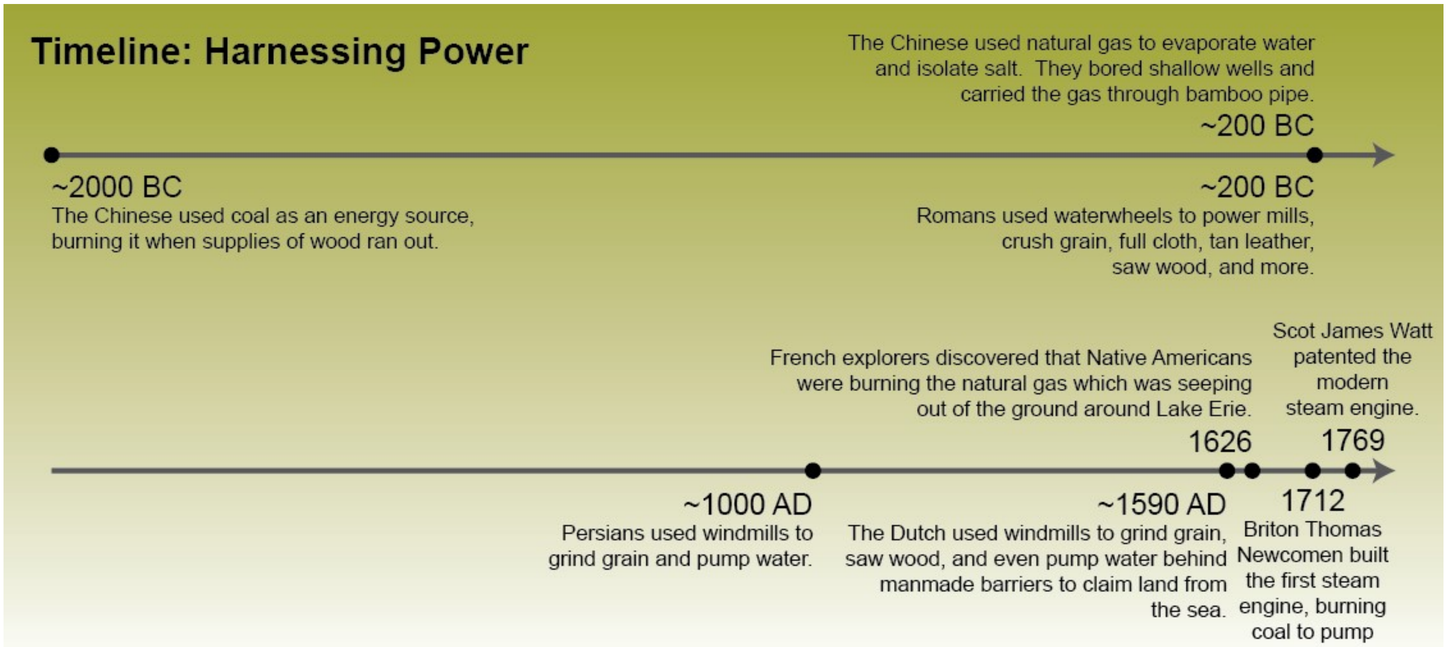
Horse	Up to 15 horsepower for short periods of time. Average about 1 horsepower for a day of work.
Blow Dryer	1000 to 1500 watts, curling irons are usually 150 watts
Lawnmower	Small push mowers are usually 3.5 to 5 hp. Riding mowers usually are 10 to 22 hp.
Electric bicycle	Usually between 300 and 750 watts although some are larger.
Car	An average car is usually between 100 and 200 horsepower. Race cars are closer to 1000 hp.
Athletes	Tour de France– 500 watts for an hour when going up hill. Track sprinters can produce 1000 watts for 13 seconds, nearly 2000 watts for short bursts.

Steam Power (1769-1820): Exploration

Wind and water are unpredictable, however, so other sources of energy were sought. In 1769, James Watt, a Scottish engineer, patented the modern-day steam engine. Steam engines quickly replaced less reliable sources of power. How do you think a steam engine works?



Your teacher will set up a steam engine and provide it with fuel. Record what happens as the engine begins to run.



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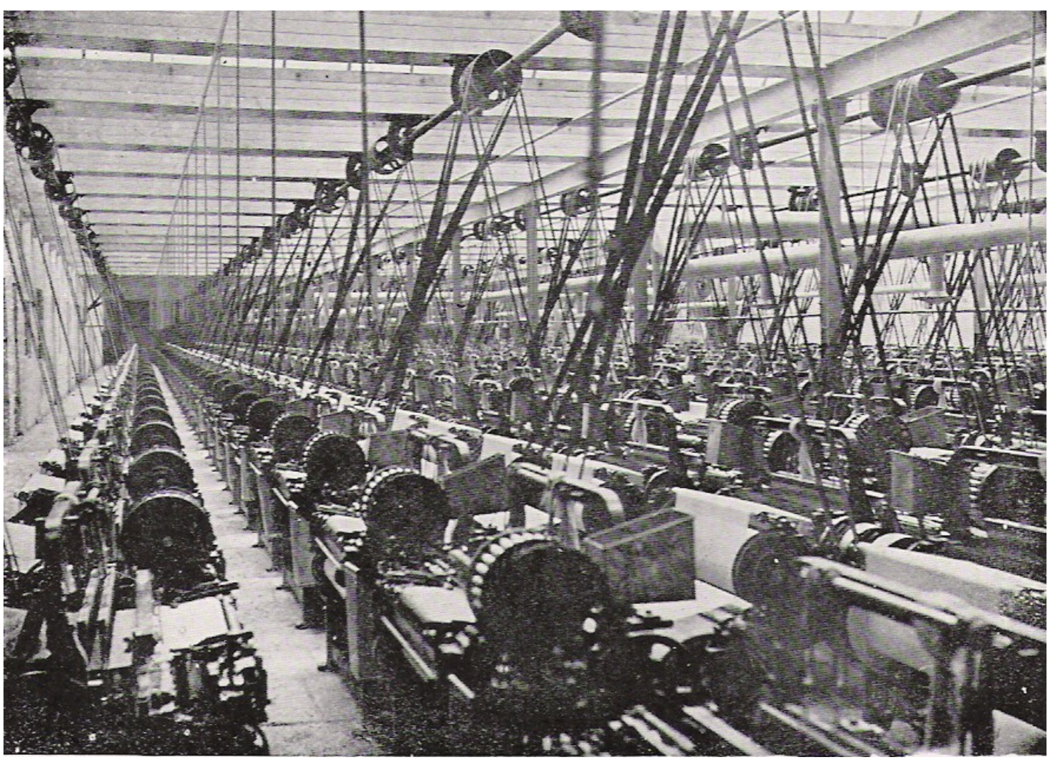
A steam engine provides great power to get work done, but only in a mechanical form – it must create motion. Factories using steam power in the 1800s transferred its mechanical motion throughout their work areas using long shafts with many pulleys and gears. Imagine how dangerous it would be to work in this factory!



The shafts, belts, and pulleys which transferred power from a steam generator to factory machinery can all be seen in this textile factory.

https://s3files.core77.com/blog/images/549455_81_58982_VVxClx9m5.jpg

Steam Power (1769-1820): Discussion

1. What is the source of energy for this steam engine?

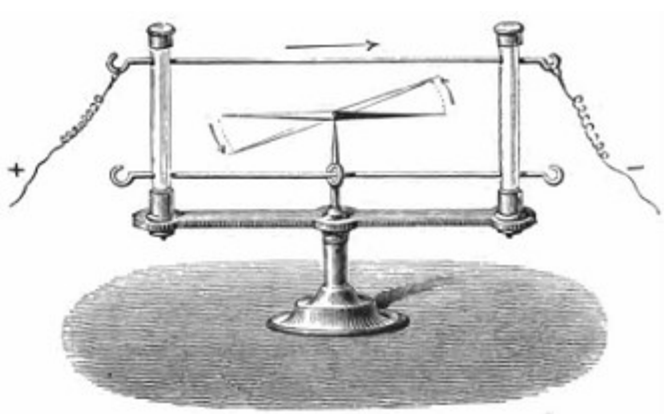
2. What happens to the water as the fuel burns?

3. Energy can be classified into many forms including thermal (heat) energy, chemical (stored) energy, mechanical energy (energy of motion), and/or electrical energy. What are the energy transformations you have seen in the steam engine?

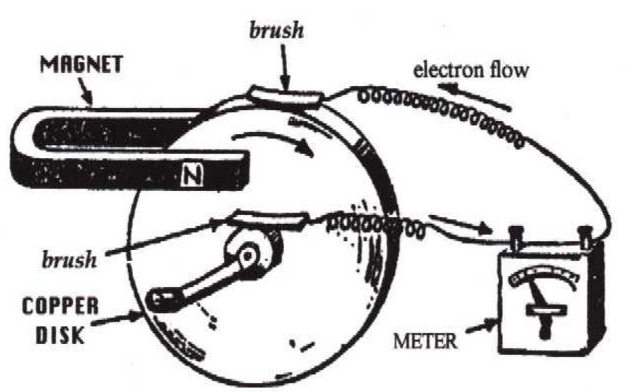
________________ → ______________ → _________________

Linking Magnetism & Electricity (1820-1831): Exploration

In 1820, Dane Hans Christian Oersted found that his compass needle moved when placed near a wire connected to a battery. A few years later, Frenchman Andre-Marie Ampere discovered that two wires with energy running in different directions could attract and repel one another, just like magnets. A decade later, Englishman Michael Faraday was able to explain why these phenomena occurred, finally describing the relationship between magnetism and electricity in 1831.



https://c8.alamy.com/comp/MR6HPR/reconstruction-of-oersteds-experiment-of-1819-when-he-discovered-that-a-magnetised-needle-could-be-deflected-by-an-electric-current-dated-19th-century-MR6HPR.jpg



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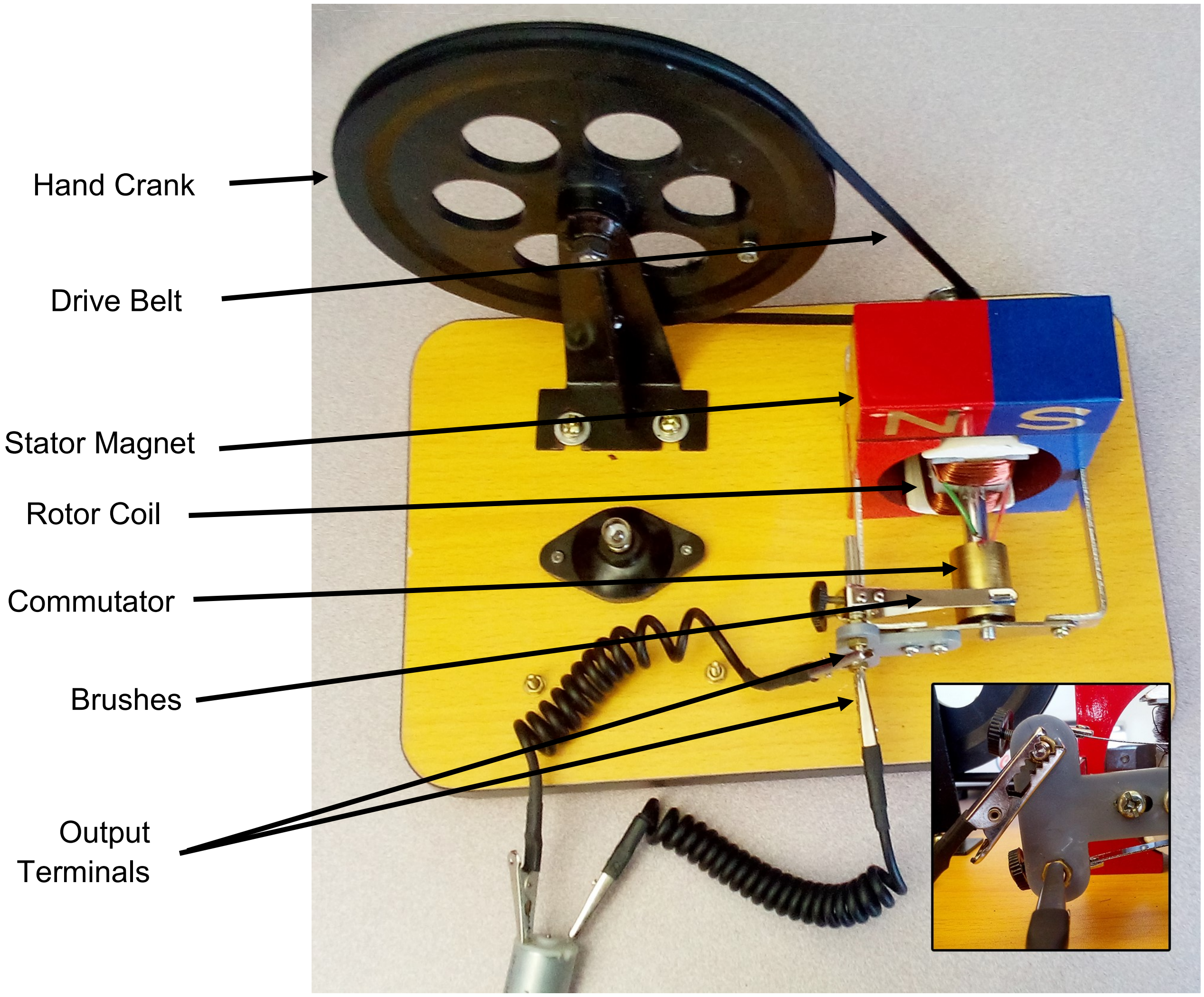


1. Without the motor or lamp connected, turn the hand-crank generator.

   What part(s) of the generator spin, and what part(s) stay in place?

2. Fold a small piece of tape around the motor shaft so you can easily see it spin.

3. Use the cables with alligator clips to connect the two little metal tabs on the back of the motor to the two output terminals on the generator. It does not matter which ones are connected.

4. Have each person on your team take a turn on the hand crank.

    What do you observe happening as you turn the crank?

    What happens if you turn the crank the other direction?

5. Disconnect the wires and set the generator aside.

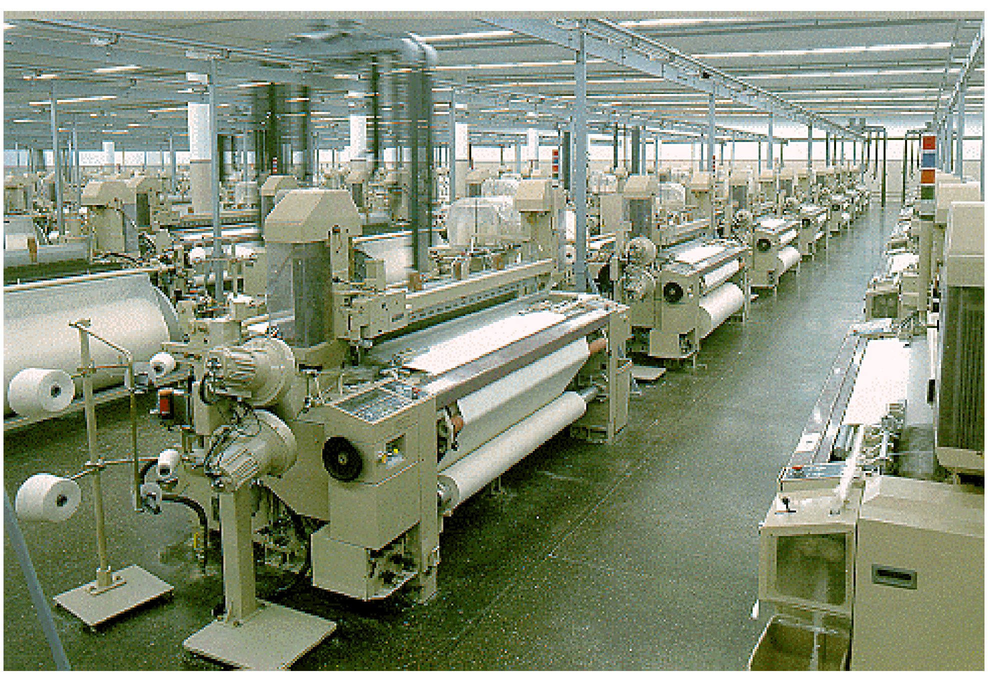
Linking Magnetism & Electricity (1820-1831): Discussion

1. Explain how you think the generator is producing electricity.

2. How does electricity get from the generator to the motor?

3. Trace the transfer of energy from the generator to the motor, using the terms thermal (heat) energy, chemical (stored) energy, mechanical energy (energy of motion), and/or electrical energy.

_________________ → _______________________ → _______________________



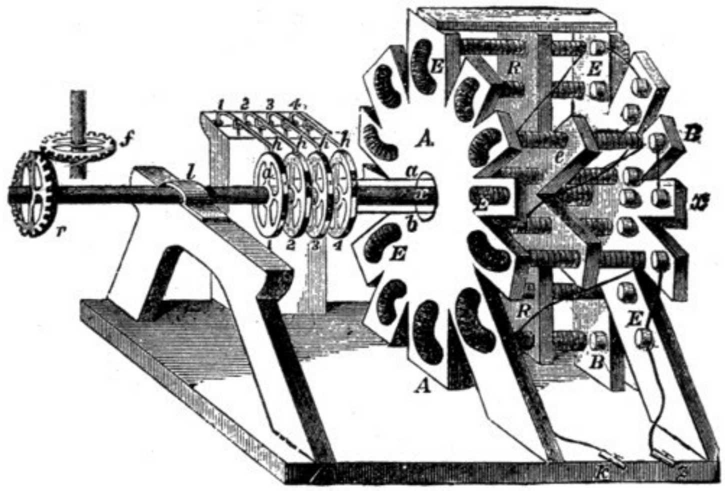
http://www.ilocis.org/documents/images/tex09fe.gif

An electric loom uses a centralized motor, so any belts or shafts can be contained within the machine to keep workers safer.

Michael Faraday discovered that moving a magnet along a wire created an electric current, building the first small-scale electrical generator. Electric generators convert mechanical energy (energy of motion) into electrical energy.

When coal was burned to produce steam, and in turn to power a generator, it created electricity. Electrical energy could then be used in many ways, including for heat, motion, and communication. One of the earliest uses of electricity was the electric motor, developed by Prussian Moritz Jacobi in 1834.

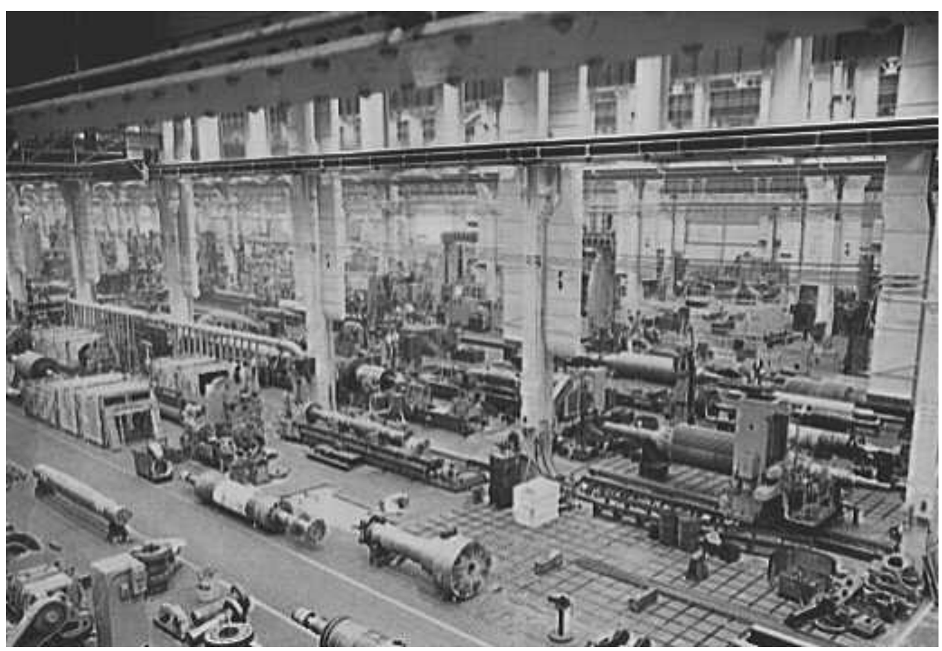
En.wikipedia.org



https://www.gutenberg.org/files/41538/41538-h/41538-h.htm#SecVI_4

Moritz von Jacobi

It did not take long before factory owners realized that the electric motor was much better than the huge shafts, pulleys, and belts that were powering their machinery. Electric motor technology improved rapidly and many machines were converted to run on electricity. This posed a problem, however. There were no power plants producing electricity. Many factories set up their own power plants. Often these were in separate buildings very close to the factory.



https://madeupinbritain.uk/Electric_Motor

New Skills for Electricity (1830-today): Exploration

Inventors soon learned that working with electricity required a new set of skills. They had to learn how to cut and strip wires and hook up circuits. They also had a lot to learn about safety.

Wires are pipes for electricity, just like hoses carry water. Similar to hoses, the plastic around the wire basically keeps the electricity from leaking out. Without the coating, the electricity could follow the incorrect path.

A circuit is a complete path for the electricity to follow. It basically has to have a way out from the generator (or battery) to the electrical device and a way back to the generator. Think of it as water flowing through a pipe with one major difference: if a water hose is cut, water leaks out. If a wire is cut, electricity stops immediately because it no longer has a way to get back to the generator.

If electricity is allowed to flow through the circuit with nothing to slow it down, such as a light or motor, the wire will get hot and probably start a fire. This is called a “direct short.” That is why it is so important that the wrong wires do not touch each other.

Electricians use different colors of wire so they don’t connect the wrong ones together. There is some variation across the country in which colors are used for what applications, but there are general rules.

Red, black, blue, and sometimes yellow wires are used for power. They are considered the “hot” wires. In this Smart Grid Construction Set, connect the red, blue, or black wires to the springs and the spring-loaded clips.

White and green wires are used for “Common” or “Ground.” These wires connect to the alligator clips. NEVER connect a white wire to a spring.

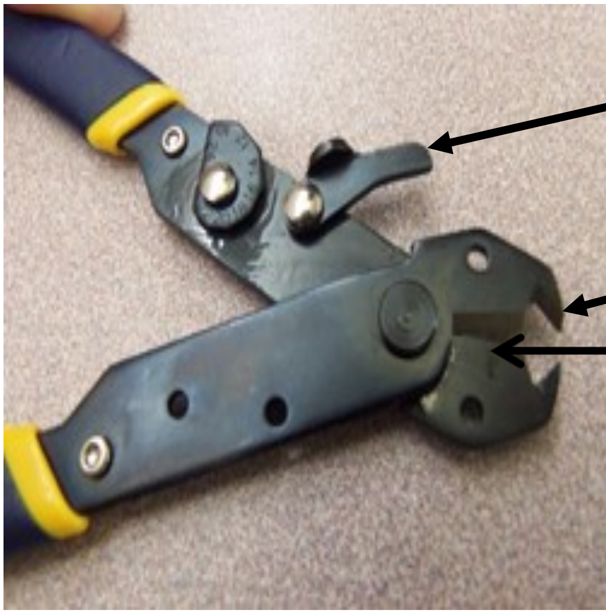
If you make a mistake and connect a spring to an alligator clip, there will be a direct short. To keep the wires from getting hot and possibly starting a fire, the power plants all have fuses. If there is too much electricity flowing in the wire, the fuse will “burn” and shut off the power. Fix the problem and then replace the fuse.

Your home has circuit breakers for protection. Perhaps you have plugged in or turned on too many devices in your home and “blew the fuse” or “tripped the circuit breaker.

Hot Wires

Ground or Common Wires

1. You will be hooking up many wires. You will need to cut them to the right length and strip the insulation off both ends using a wire cutter/stripper.



Locking lever

Put wire here to strip

Put wire here to cut

2. Adjust the cutter to strip the wire by turning the little dial on the side. It should be set on 20. This dial keeps the jaws open just enough so the Vee-shaped part will cut through the plastic coating but not through the wire itself. You might want to hold it with a small piece of tape.

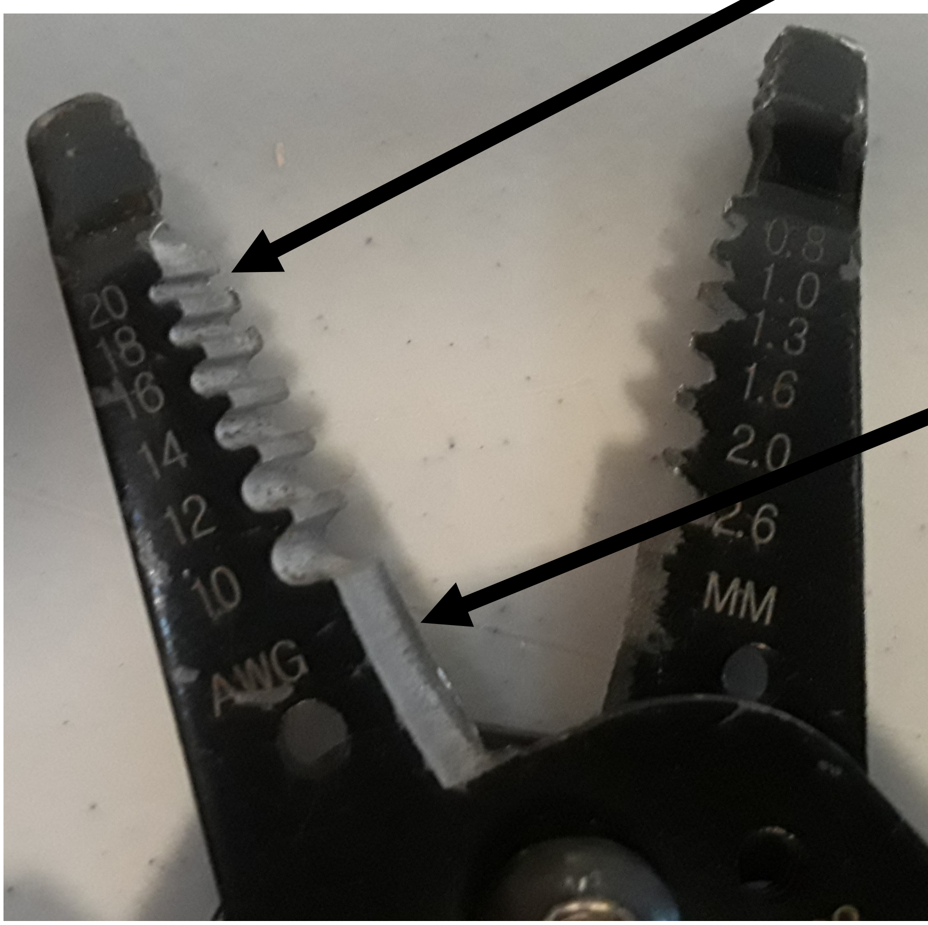
Set to 20 here.

Notice the little gap here

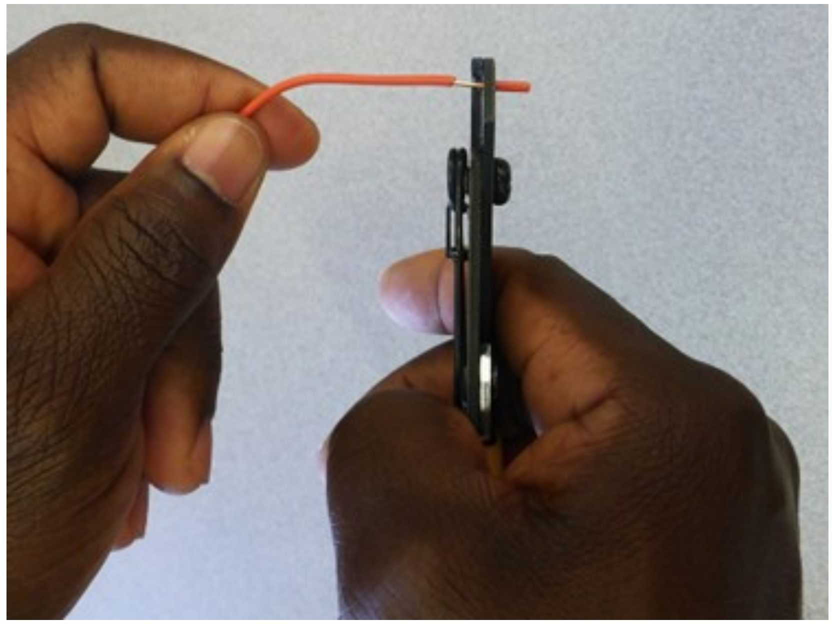
3. Your wire tool might look like this:

Use this notch to strip the wire.

Cut here



4. Measure the right length of wire by holding it between the two connections. A bit too long is much better than a bit too short.



5. Cut it to the right length using the cutter blade on the wire tool.

6. Strip about 1/2 inch (about 1 cm) of plastic insulation off both ends of the wire.

7. To hook up a wire, simply bend the spring to the side and stick the bare end of the wire into the side of the spring between the coils. Be sure that the spring is touching the bare end of the wire and not the plastic insulator. To insert a second wire into the same spring, bend it the other direction so that pinches the first one in while the second is inserted.

New Skills for Electricity (1830-today): Discussion

1. What is a circuit?

2. What is a "Direct Short?"

3. How do electricians know what wires to hook together and which ones can never be connected?

4. Can a black or red wire ever be connected to a white or green wire? Why or why not?

5. What happens if a wire carries too much electricity?

6. What device keeps the wires from getting hot and possibly starting a fire in your home?

Careers in Energy

Not only did the electrical grid require new skills, but it also created a lot of very good jobs. As you work with this Smart Grid system you may want to explore a career in Energy.

Listed below are a few jobs. Your teacher has several more. This data came from the Occupational Outlook Handbook. Go to www.bls.gov for more information.

All of these careers require a high school education. It usually takes 2 years to earn an Associates Degree and 4 years to earn a Bachelors. Many offer on-the-job training.

When considering the possibility of getting a job in any of these areas, consider not only the % increase, but also the number of jobs. For example, a 57% increase in Wind Turbine technician results in 3,800 new jobs where a 2% increase for electrical engineers adds 8,000 new jobs.

Career Title	Description	Education Required	Median Salary In 2018	Job Outlook 2018-2028
Line installers and repairers	install or repair electrical power systems and telecommunications cables, including fiber optic	High school diploma. Long-term on-the-job training	$65,880 per year $31.67 per hour	+4% increase +10,700 jobs
Solar photovoltaic (PV) installers	assemble, install, and maintain solar panel systems on rooftops or other structures.	High school diploma. Moderate-term on-the-job training	$42,680 per year $20.52 per hour	+63% increase +6,100 jobs
Wind turbine service technicians	install, maintain, and repair wind turbines.	High school diploma. Long-term on-the-job training	$54,370 per year $26.14 per hour	+57% increase +3,800 jobs
Electrical engineers	design, develop, test, and supervise the manufacture of electrical equipment	Bachelor's degree	$99,070 per year $47.63 per hour	+2% increase +8,000 jobs
Environmental engineers	use the principles of engineering, soil science, biology, and chemistry to develop solutions to environmental problems.	Bachelor's degree	$87,620 per year $42.13 per hour	+5% increase +2,900 jobs
Electricians	install, maintain, and repair electrical power, communications, lighting, and control systems.	Associate's degree and/or on-the-job training	$55,190 per year $26.53 per hour	+10% increase +74,100 jobs

Electrical Power (1830-1880): Exploration

New technology is always expensive so the people to use it first are usually those who can profit from it. Factory owners found that electric motors were more efficient, more adaptable, quieter, and safer than other forms of power. But, they needed electricity. They had to make their own.

Most power plants make electricity by burning a fuel to turn water into steam. The steam turns a turbine that spins a generator. This really has not changed much in the past 150 years. In the 1800s, however, they used wood or coal. Today we use coal and natural gas to produce a bit less than half of the electricity in Illinois. Nuclear power makes the other half. Wind power has been used to generate electricity for nearly 150 years, but it has never been a major source of power because it is not reliable.

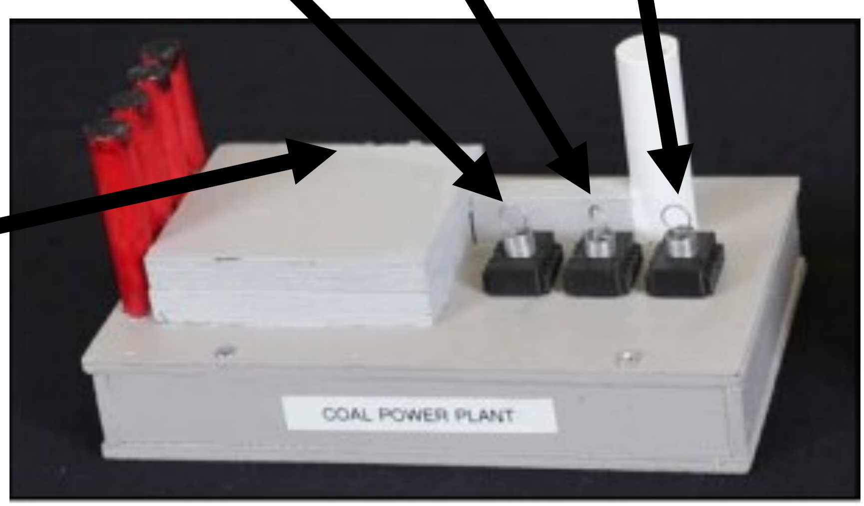
1. Select one of the power plants. Notice it has three springs on the top and an alligator clip on the side. All power plants produce Three-Phase Alternating Current (AC). As the generator spins, the electricity alternates from positive to negative 60 times each second, also known as 60 Hertz. This is why you sometimes can hear a buzzing sound around electrical equipment and lights. With three-phase generators, each phase is 120 degrees of rotation behind the previous. One phase is fully positive, then as that phase starts to turn negative the second phase is fully positive and before it has a chance to change to negative, the third phase is fully positive. Think of it as waves that are very close together. Houses usually only need a single phase, and it does not matter which one. Factories, however, like to use 3-phase power because it makes their motors more powerful and their machines run much smoother. This is similar to pedaling a bicycle with only one leg compared to using both legs. Imagine how fast you could go on a bicycle if you had three-phase pedaling!

http://www.tabula.ge/en/story/120489-gig-building-300-megawatt-coal-run-thermal-power-station

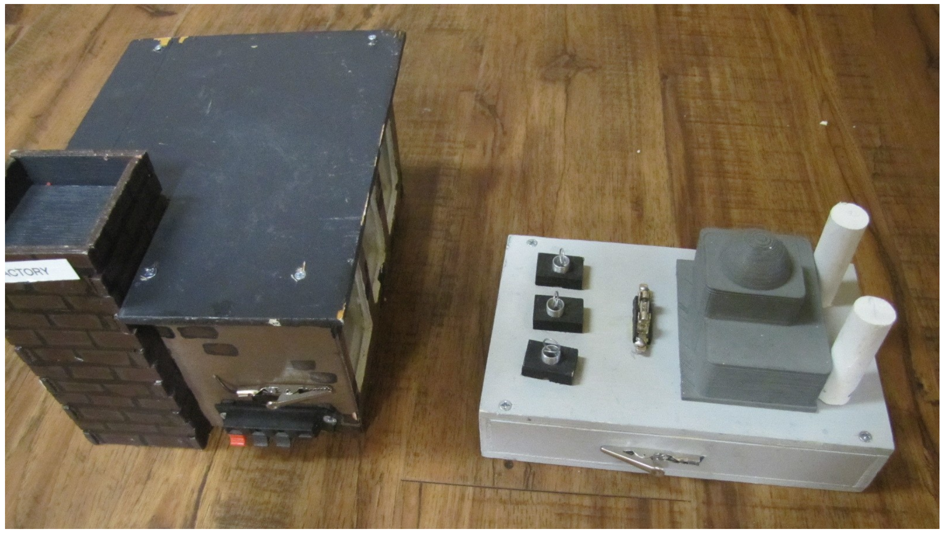
Attach all HOT wires to springs

RED **BLACK** **BLUE**

Attach all COMMON or GROUND wires to the alligator clip .



3. Just like 150 years ago, place the power plant beside the factory.
4. Measure, cut, and strip both ends of a white wire and connect it between the alligator clips.
5. Measure, cut, and strip both ends of a red, black, and blue wire and connect each between a spring and a clip on the factory. One of the clips on the factory is red, but that does not mean it has to be a red wire.



6. Ask your teacher to inspect your work to make sure there are no direct shorts.
7. Connect the power plant to the Power Company headquarters office building using a cable with audio jack ends.

8. Turn on the power. What happens?

Electrical Power (1830-1880): Discussion

1. Before the use of electricity, what did factories use to power their machinery?

2. What are some of the benefits of electric motors over other types of power?

3. What is Alternating Current?

4. Why is three-phase electricity better for motors and factory machinery than using a single phase?

Electrical Enlightenment (1880-1920): Exploration

https://greenwichmag.com/in-full-swing/

1. Set out the hand-crank generator.
2. Connect the output terminals to the light bulb.
3. Each person on your team should take a turn on the hand crank.
4. What do you observe happening as you turn the crank?
5. Disconnect the wires and put the generator away. You will not need it again.

Until the late 1800s, electricity was only for factories and big commercial buildings. Nobody ever thought they would need it in their home. That attitude changed quickly with the invention of the light bulb. Now with just a flip of a switch, people could have instant light. Inventors started coming up with more and more appliances that could run on electricity. Soon, everybody wanted their house hooked up to the power plant.

6. Turn off the power to the headquarters office.
7. Set a house near the factory.
8. Measure, cut, and strip both ends of a red, black, or blue wire.
9. Connect the spring on the house to one of the springs on the power plant.
10. Measure, cut, and strip both ends of a white wire.
11. Connect the alligator clip on the house to the alligator clip on the power plant.
12. Check your wiring for shorts.
13. When you are certain it is correct, turn on the power to the headquarters office.

    What happens?

Electrical Enlightenment (1880-1920): Discussion

1. Was there a difference when you turned the crank faster or slower? What was the change, and why do you think it occurred?

2. How are electric lamps an improvement over candles and other lights?

3. Who do you suppose were the first people to get electricity in their homes? Why?

4. How did the electric light bulb change the way people lived?

In 1841, Frederik de Moleyns, a British physicist, patented the first electric light bulb. Thomas Alva Edison is better known for his work with the light bulb because he provided both bulb and power source.

Edison opened his Pearl Street Station in 1882, which provided power to electric lamps in a one square-mile area of New York City. His plant, which served 85 customers and 400 lamps, primarily provided electricity to influential customers like the New York Stock Exchange, the nation's largest newspapers, and banking tycoon J.P. Morgan.

https://images.app.goo.gl/zheqgFTAvDuVmHxXA

The Pearl Street Station showed the world some of the capabilities of electricity. What was needed, however, was an inexpensive way to distribute electricity to everyone. When prices came down, what had primarily been a tool for industry or a luxury for the wealthy quickly transformed the lives of American citizens.

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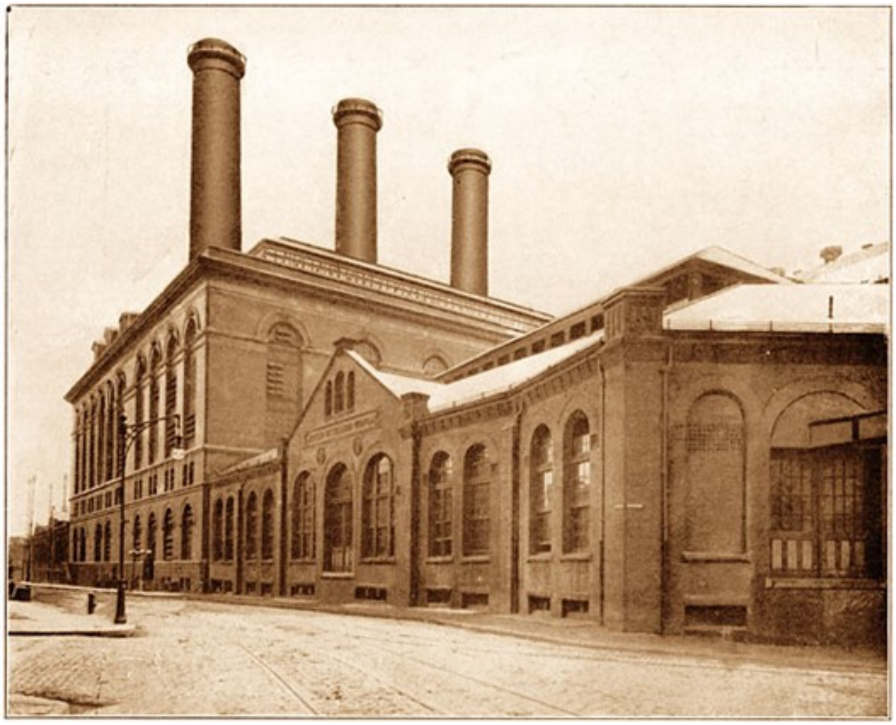


Edison's 1882 Pearl Street Station was a coal-powered plant. The first windmill used to generate electricity came soon after (in 1888) when Charles F. Brush built a turbine to power lights and motors at his home in Cleveland, OH.

While natural gas was used in different ways over time, the first natural gas power plant as we know it today was built for Oklahoma Gas & Electric in 1949.

https://www.nytimes.com/2008/05/04/nyregion/

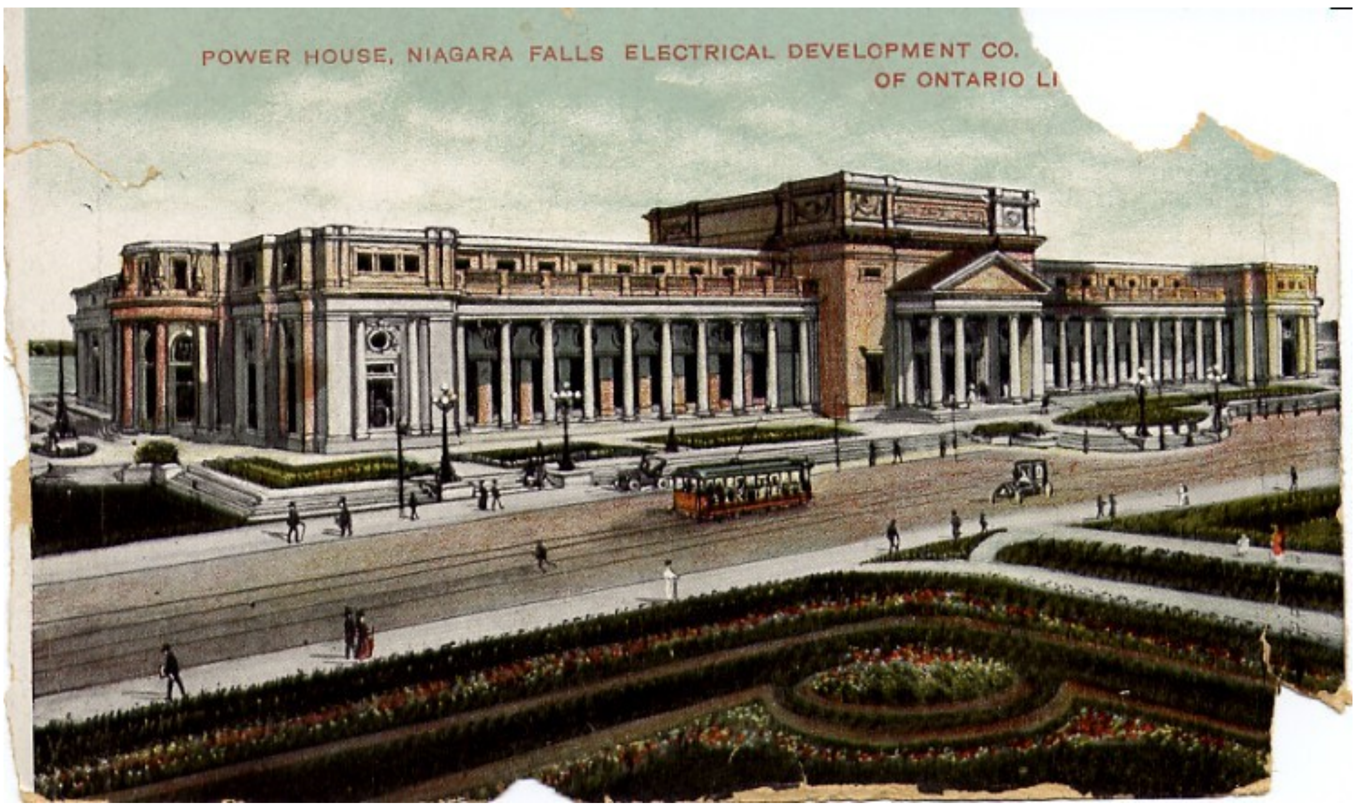
The first nuclear and solar plants would come much later – the first nuclear power plant was built at Calder Hall in Cumbria, U.K. in 1956 and the first modern solar plant was built in the Mojave Desert in 1981.

https://www.nytimes.com/2008/05/04/nyregion/thecity/04cone.html

Thomas Edison's Pearl Street Station had a major flaw. It used direct current which can only travel short distances. In 1886, Frank Sprague used an alternating current generator and transformer to make the first long-distance AC power transmission in Great Barrington, MA.

Alternating current can travel much longer distances than direct current. In 1895, George Westinghouse partnered with Nicola Tesla to build a water turbine at Niagara Falls. It supplied power to the town of Buffalo, NY about 20 miles away. Unfortunately, alternating current transmission still had a flaw – the low-voltage lines lost a large amount of energy to electrical resistance.

Michael Faraday had already solved this problem 50 years earlier. His early work on induction allowed Westinghouse and Tesla to increase and decrease the voltage using transformers. Higher voltages could be transmitted longer distances with less loss.



https://www.niagarafallsmarriott.com/niagara-seasons/toronto-power-generating-

Building the Grid (1886-1900): Exploration

1. Unplug the thick cable to the Headquarters Office before changing the wires.

2. Disconnect any existing power lines from your power plant.

3. Place the power plant and Headquarters office at one end of your table and set the homes, shops, factory, etc. around the edges of the table.

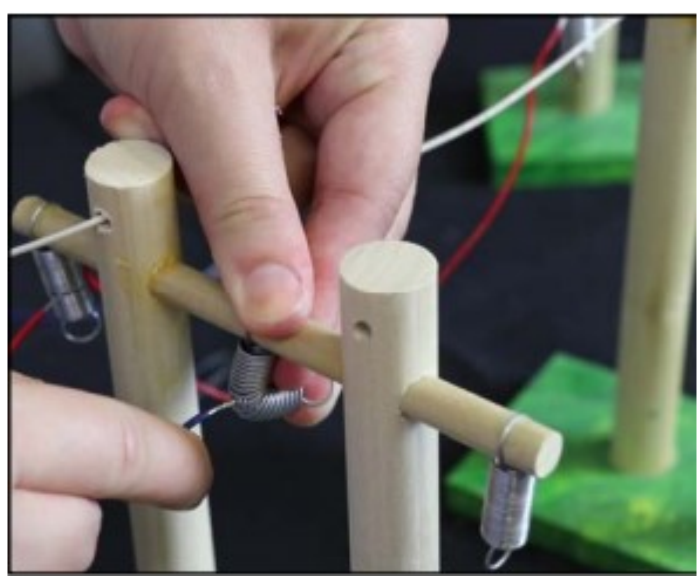
4. Basically, the taller the pole or the higher the wire is off the ground, the higher the voltage that the line carries. Transformers are used to change the voltage of a line. Notice that the springs on the power plant are on transformers. They “step up” the voltage so that it can go a long distance to the customers. A substation has several transformers.

5. Set up several high voltage H poles in a line from the power plant to the middle of your table.

6. Measure, cut, and strip both ends of red, black, and blue wires and connect them from the springs on the power plant to the first high voltage pole.

7. Continue connecting from one pole to the next until they connect to the factory.

8. Thread a white wire through the holes in the top of the H-poles to extend all the way from the factory to the power plant.

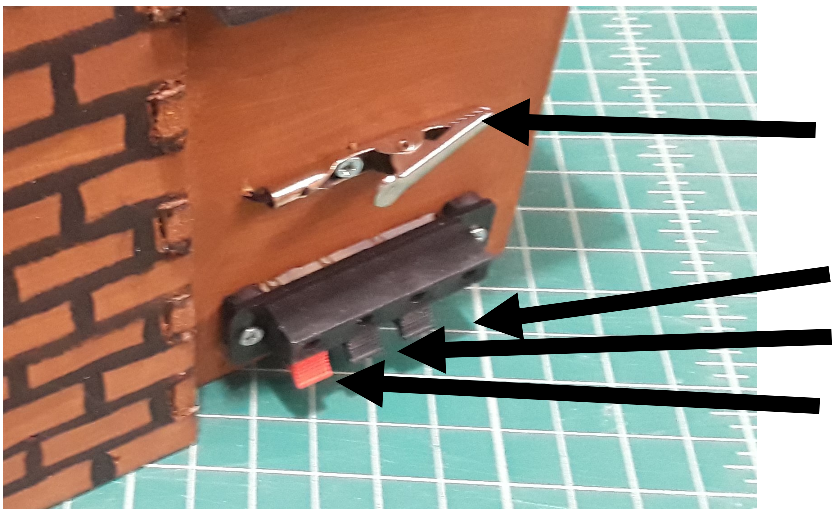


9. Cut the wire to the right length and strip the ends. Connect them to the alligator clips on the factory and the power plant.

10. Check your wires and turn on the power. Does the factory function?

11. Turn off the power after testing.

12. Connect red, black, and blue wires to other customers that need 3-phase electricity. Simply branch off the springs on the towers.



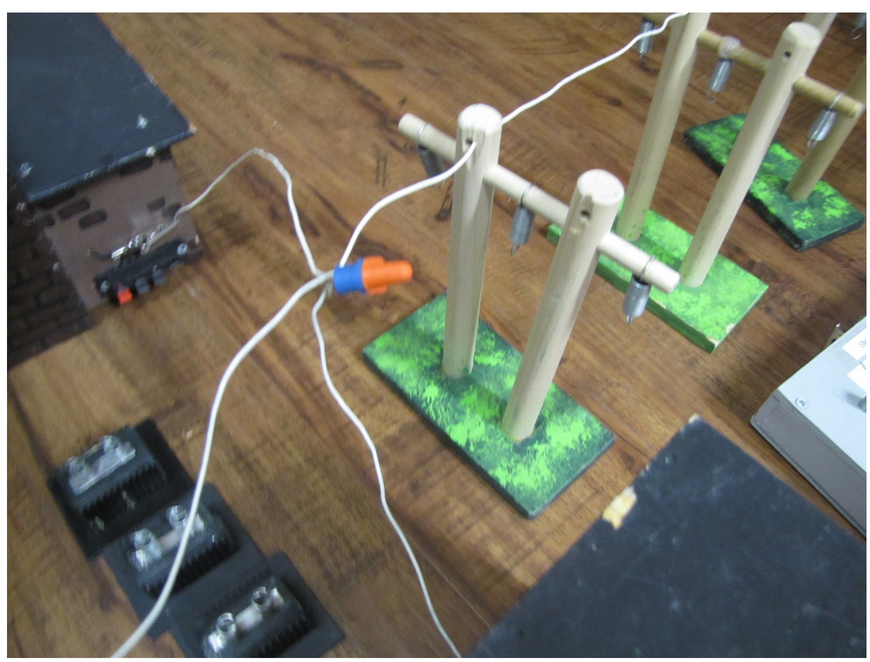
White wire here

RED

BLACK **Wires here**

BLUE

13. Remember that you must have a complete circuit. The electricity has to have a way to get back to the power plant. One method is to tie your white wire to an existing white wire. Cut the existing wire and strip both ends. Insert both ends and the end of your new wire into a wire nut. Twist them together with the nut.



14. Check the wiring and turn on the power. Turn off the power when you are done testing.

Before distributing electricity to your neighborhood, the voltage has to be "stepped down". The wires you see on your street are usually about 7200 volts. That is still very dangerous, but not nearly as dangerous as the 120,000 volts or more in the transmission lines. The 7200 volt line is stepped down again with a bucket transformer mounted on the pole just outside your house or by the transformer inside the green box in your backyard.

Connect a red, black, or blue wire from an H pole to one side of a transformer.

1. Using that same color wire, connect from pole to pole to get to a house. The pole nearest the house should have a bucket transformer on it.

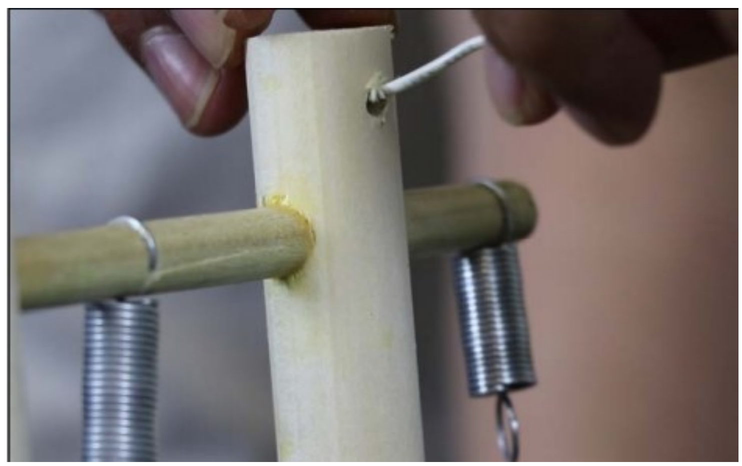
2. Hook up other wires and transformers to get power to every customer.

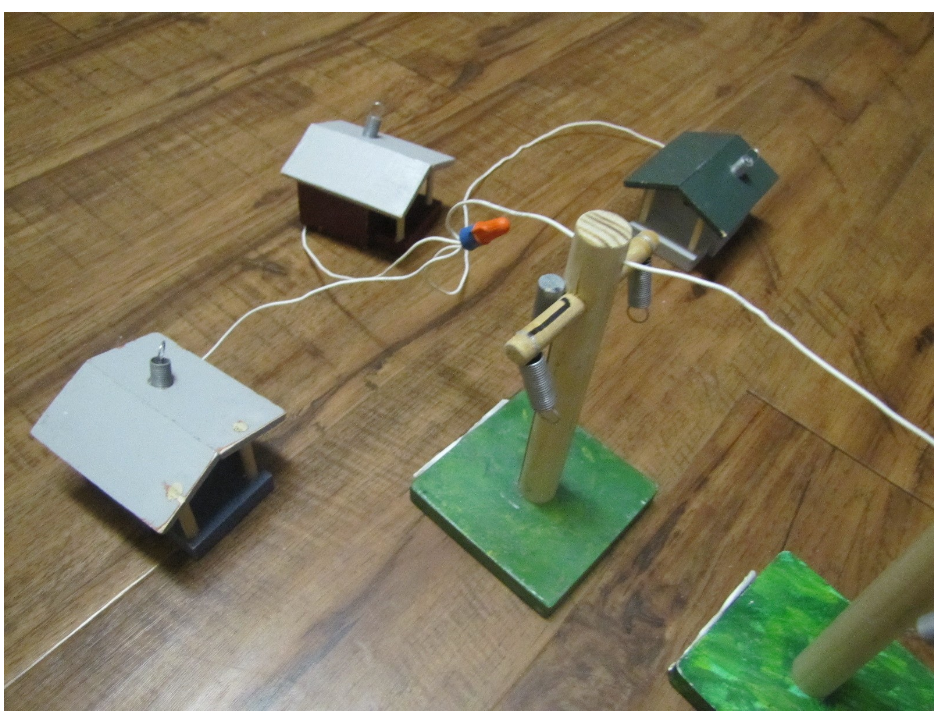
3. Run the white wire through the holes in the top of the poles all the way back to the power plant.

4. Connect the alligator clips of all of the houses and customers to the main white wire.

5. When you are certain everything is hooked up correctly, turn on the power.

6. Do all customers have power? If not, what is wrong?





Building the Grid (1886-1900): Discussion

1. What is the advantage of high-voltage power transmission? Why couldn't all power lines be low voltage?

2. What is the purpose of a substation?

3. Why do substations always have high fences around them?

4. Are there any substations, transformers mounted on poles or green boxes near your home?

Safety: Never go near a downed power line. Get away and call 911 immediately. Never do anything that might connect you to a power line. A kite string, ladder, or even digging into a buried power line with a shovel can cause severe burns or death.

electrical-engineering-portal.com

https://energyeducation.ca/encyclopedia/Electrical_substation

Most outlets in a house are 120 volts. Most houses can draw up to 100 amps at any given time. The maximum power an average house could ever use is 120 volts x 100 amps = 12,000 watts. Houses seldom use that much power but the grid must provide for it. Three houses in the same neighborhood could draw 36,000 watts. At 120 volts, that would be 300 amps.
watts=volts x amps   amps=watts/volts

36,000 watts / 120 volts = 300 amps

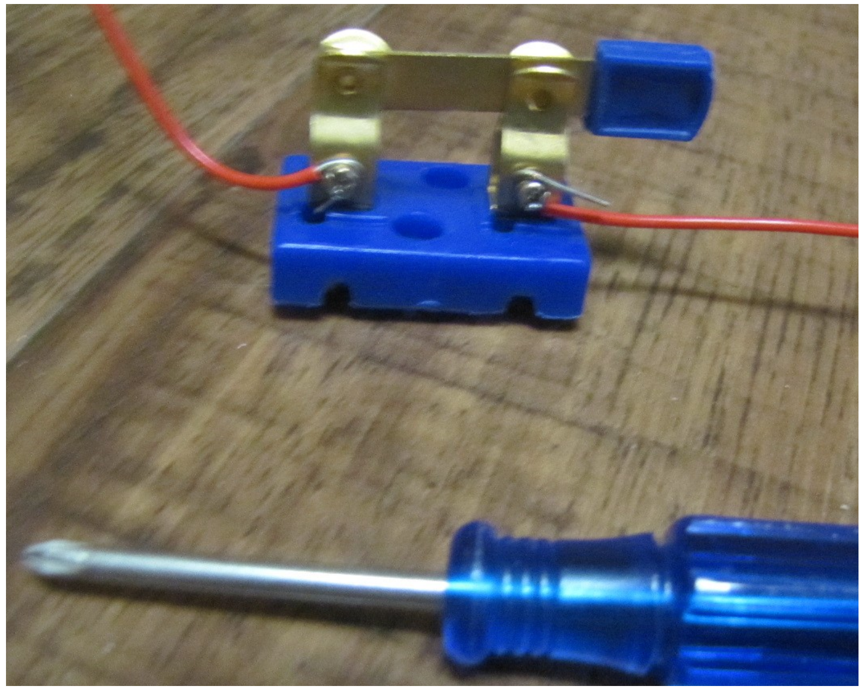
300 amps is a lot of current which requires large, expensive wire. To reduce the current, electric companies increase the voltage coming to the neighborhood to 7200 volts. Now 12,000 watts / 7200 volts = 1.6 amps. A smaller, cheaper wire can be used. A bucket transformer reduces the voltage to 120 volts right before it goes into the house.

Research electrical use of your school, local businesses, and industries and calculate watts, volts, and amps.

https://internationalelectricalsuppliers.weebly.com/

Switching the Grid (1900-1950): Exploration

As more and more customers were tied to the grid, a system had to be developed to shut off power to some locations and redirect it from others. Switches were installed at various places in the grid to control the flow of electricity.



1. Switches are always found at the substations with the transformers. They also can be found on many poles.
2. To hook up a switch, strip the ends of the wires and bend the bare wire around the screws. Tighten the screws to hold the wires in place.
3. Put several switches into your grid so that some circuits can be turned off while others stay on.
4. The switches ALWAYS go on the hot wire (red, black, or blue) and NEVER on the ground or common wire (white or green).

Switching the Grid (1900-1950): Discussion

1. What does a switch do?

2. Why is it so important to have lots of switches in the grid?

3. How did the installation of switches promote safety and lead to fewer accidents?

The first long-distance high-voltage transmission line was established in 1917, carrying power from a steam plant at a coal mine to the city of Canton, OH 55 miles away. The ability to transmit energy efficiently over long distances transformed the way power companies began to operate – the Canton plant virtually eliminated the expensive transportation of coal since the power plant and coal mine were located in the same place!

Transporting electrical power over long distances, however, introduces another new problem: if a customer lost power, there was a much longer line to inspect for problems. You have probably already experienced how hard it can be to find a problem in your grid. As multiple power plants and multiple grids were interconnected, the grid gets larger and more complex, making it very, very difficult to pin-point a problem and fix it quickly. A smarter system was needed. Electricians added sensors to key locations to monitor electrical power.

https://woodpoles.org/

PHOTOGRAPH BY STATE ARCHIVES OF NORTH CAROLINA

Monitoring the Grid (1950- today): Exploration

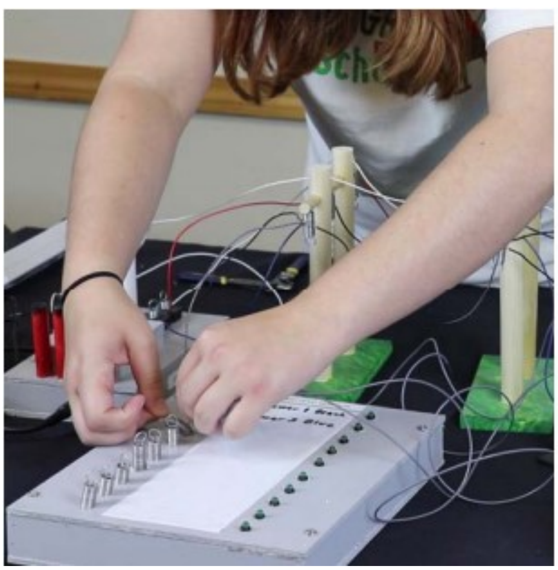
There have been devices used for decades that monitor the flow of electricity in the grid. Since they were rather expensive, only a few were installed. Over the years as technology advances, these sensors and monitors have become more and more “smart,” leading to the development of the “Smart Grid.”

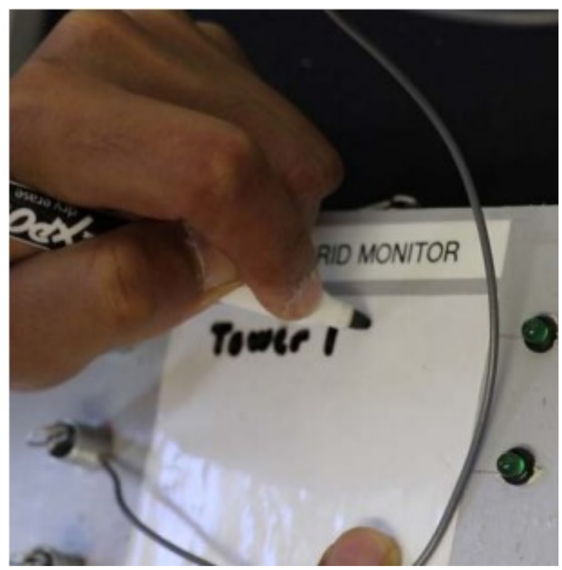
1. Connect a long white wire from your Smart Grid Monitor to the alligator clip on the power plant.

2. Use a grey wire to connect from the top spring on the monitor to any spring on your grid.

3. Record the number for this location on the panel using a dry erase marker.

4. What happens when you connect this wire? What does the Smart Grid Monitor tell you?





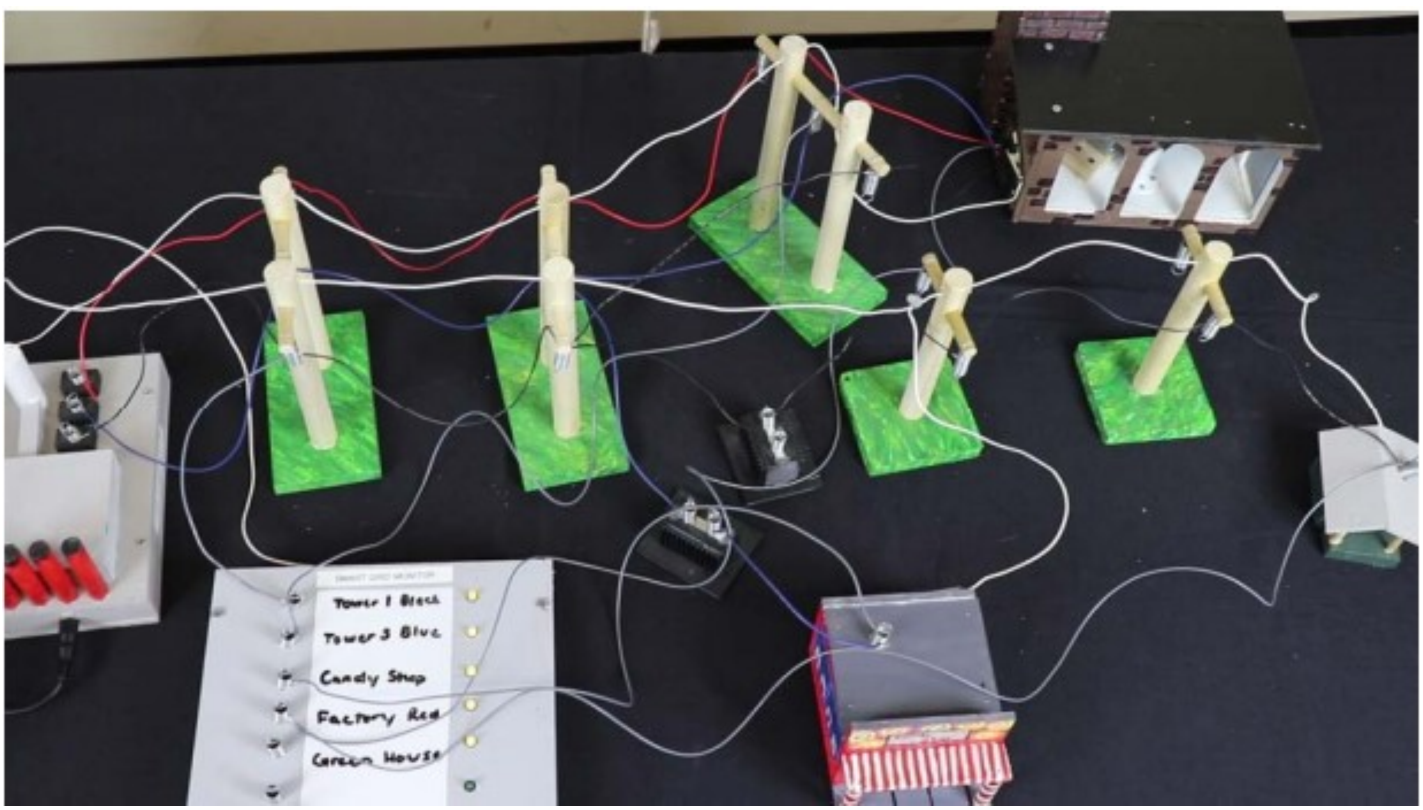
5. Repeat the instructions above to connect grey wires to 4 main locations throughout your grid.

6. Since you only have a few sensors, where should you put them? Record the number of the location on the monitor tablet.

7. Have a team member disconnect a wire from somewhere in the middle of your grid while everyone else watches the Smart Grid Monitor.

Did any of the sensor lights turn off? Why or why not?

8. Have a team member disconnect a second wire from somewhere else in your grid while everyone else watches the Smart Grid Monitor. Instead of fixing the problem, use your monitor and switches to reroute the electrical power around the problem to the affected customers. You may need to move some sensors and switches.



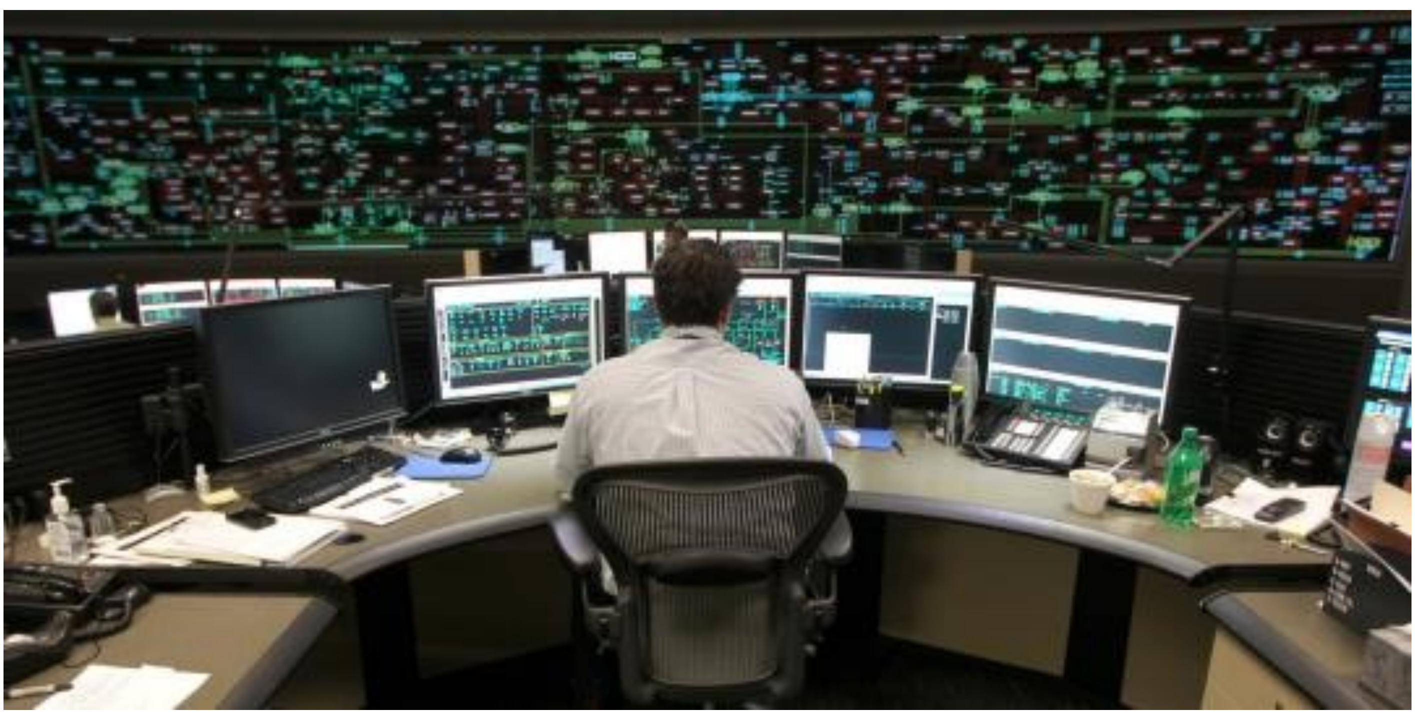
Monitoring the Grid (1950-today): Discussion

1. How did you decide where to put your sensors?

2. How did these sensors help you find problems?

3. How could the monitor system be improved to find problems more accurately?

4. Because sensors were expensive, they were reserved for important locations and the “big” customers (like factories and commercial buildings). They were not installed on homes. How did the power company know if the electricity went off at a house?



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In 1953, American Electric Power commissioned a seven-state interconnected grid to share power generation resources and provide a level of redundancy if a plant experienced an unexpected failure. This required a lot of switching power, including switches to allow customers access to power from a wide variety of power plants.

The Grid Grows (1950-today): Exploration

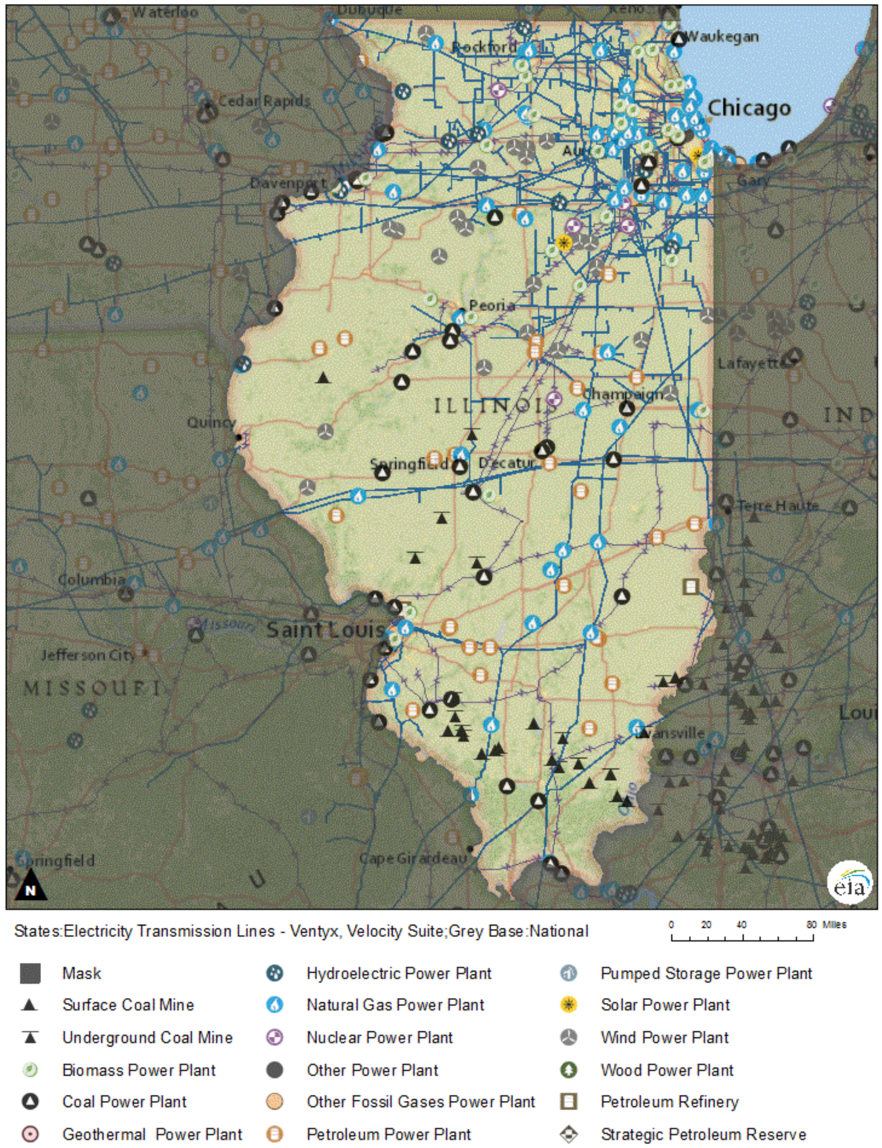
1. Unplug the thick cable to the Headquarters Office before changing the wires.

2. Move your entire table (your entire grid) so it is alongside at least one other group.

3. Working with the other group, figure out a way to use switches to control how power from either one of the power plants can reach your customers.

4. How do you need to change your grid to have a switch control which power plants provide power?

5. How do you need to change your grid to have a switch control which neighborhoods and customers receive power?



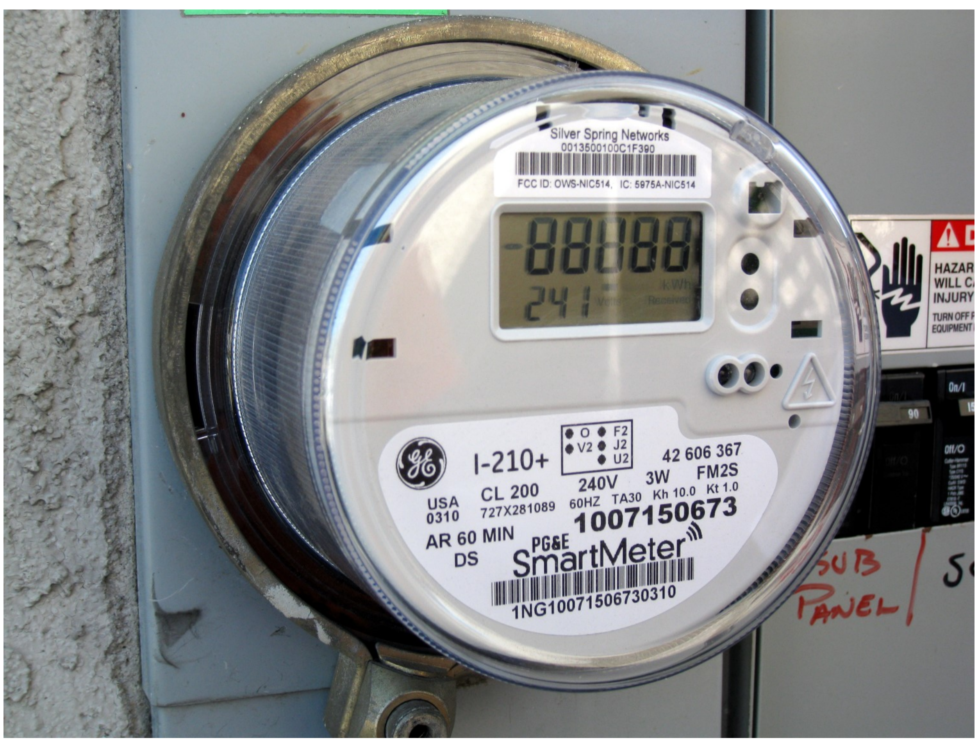
http://www.eia.gov/state/

The Grid Grows (1950-today): Discussion

1. Why is it a good idea to have the grids of cities, states, and entire regions interconnected?

2. How did switches help your customers?

3. How do your sensors help control the grid and locate problems?



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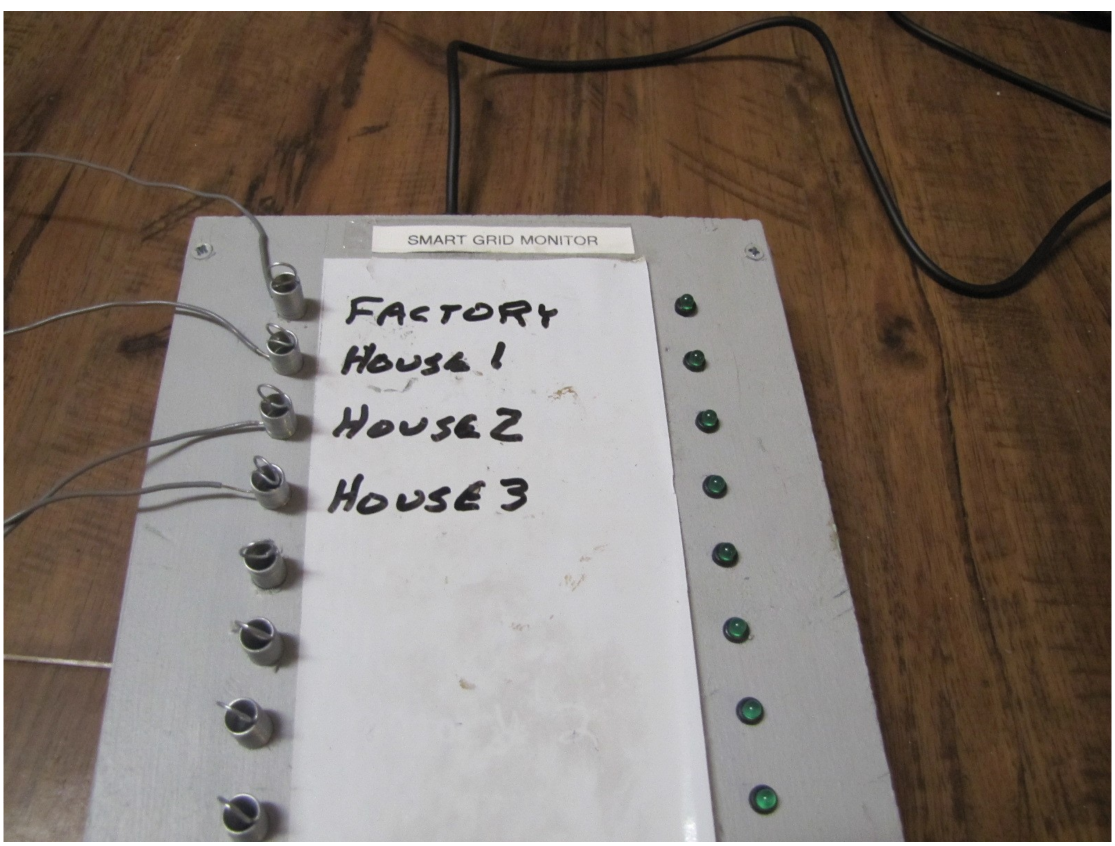
Making the Grid Smart (2000-2020): Exploration

1. Place smart sensors wherever you need them throughout your entire grid. Be sure to label them on your monitor tablet.

2. Disconnect power lines to see if you can use your Smart Grid Monitor to quickly find problems.

One of the main advantages of a Smart Grid system is that the sensors control the switches. When a problem is detected by Smart Grid sensors, switches are automatically opened or closed at various locations throughout the grid to reroute power around the problem.

A Smart Meter on a house is a sensor that is in two-way communication with the power company. All Smart Meters transmit data about power use and receive commands that adjust the circuits to assure that all homes have enough power. If a Smart Meter has not yet been installed on your home, it will be soon.



Making the Grid Smart (2000-2020): Discussion

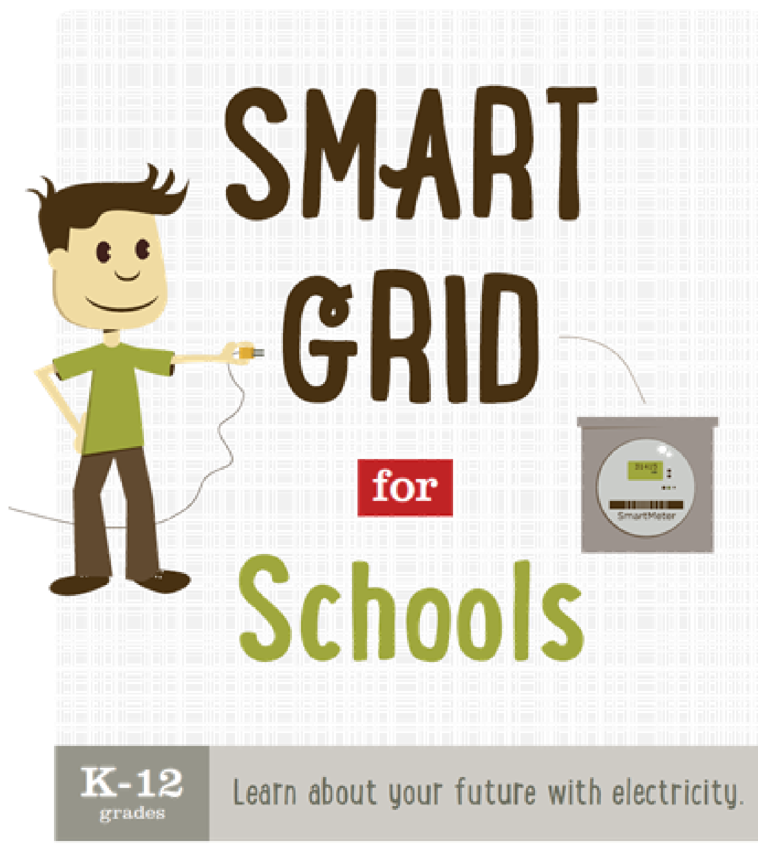
1. How did you decide where to put the sensors?

2. What can you do with the sensors that you cannot do without them?

3. List some of the advantages of allowing the sensors to automatically control the switches.

4. Explain why is it is a good idea for power companies to put Smart Meters on all homes in Illinois.

You now have now built a very large and complex grid system with lots of power plants, sub-stations, and customers, but this is still a simple representation of the actual grid. Although the grid is large and complex, it is still based on 100-year-old technology. If Edison, Westinghouse, and Tesla were alive today, they would recognize our current system. It works well now, but it may struggle to meet projected future demands. For example, nearly all cars are currently powered by gasoline. As electric cars become more prevalent, the energy to move them will be purchased from the electrical grid, not the gas station. This alone could greatly increase electricity demand. The Smart Grid is one big step towards managing electrical production and consumption, making our system much more efficient.



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Illinois State University

ISEIF

Follow Up Discussion Questions

- There were four different power plants available: coal, natural gas, nuclear, and renewable energy (both solar and wind power). What is the difference between these plants?

- How do the different power plants impact the environment?
  Coal:
  Natural Gas:
  Nuclear:
  Renewable:

- Government initiatives are spurring investment in solar and wind energy. How is this beneficial?

  Why would some people suggest that natural gas is a better investment?

- If your school were to install a way to generate its own power, which method should they purchase? Why?

- Suggest some ways that you could reduce energy consumption.

- There are some people opposed to the installation of Smart Meters on their homes. What reasons are given? Are their reasons valid?

- Describe your vision for the future of electricity.

The STEM of Energy

Here is some information about electricity that you teacher may want to use to help you better understand circuits and how they work.

Science is the study of the natural world. In this case, electricity. During this study, patterns are discovered. Scientist learn that certain things work in predicable ways. These patterns are written as mathematics equations. Engineers use these patterns to design products and systems that we call *technology*. You have already worked with some of the Engineering and Technology. Here is some of the Science and Mathematics.

Electricity in a wire is a lot like water flowing in a hose.

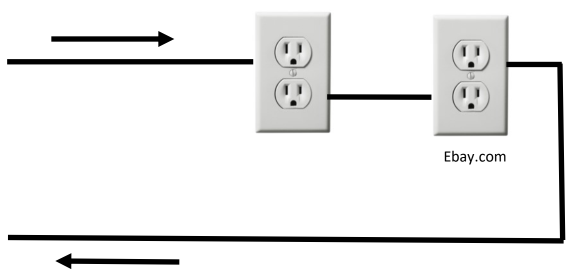
- The volume of electricity is called the "current" and is measured in **Amps**.
- The pressure that pushes the electricity is measured in **Volts.**
- The force that tries to slow it down is call "resistance" and is measured in **Ohms.** Think of it as how much you squeeze the hose and reduce the flow.

Upsbatterycenter.com

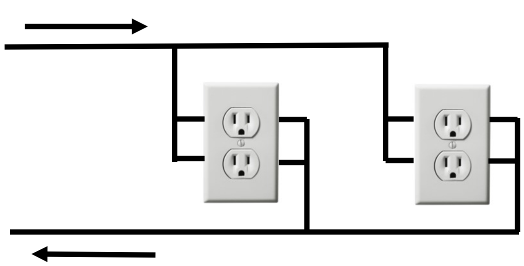
A scientist named Georg Simon Ohm discovered the pattern that is now known as Ohm's Law. It states that:

Volts = Ohms x Amps so **Amps** = Volts / Ohms and **Ohms** = Volts / Amps

Series Circuit:


Ebay.com

Parallel Circuit:



Unlike water in a hose, however, electricity only flows from its source back to its source. This pathway is called a "circuit." If you cut a wire, the flow stops. You do not get a puddle of electricity spilled on the floor.

There are two types of circuits, series and parallel.

In a series circuit, the electricity has only one path and goes through every device. If a device is not plugged in and turned on, the electricity stops because it has no other option. Obviously that would not work in your house.

Houses are wired in Parallel. There are many pathways for the electricity to flow. This provides the same volts to every outlet and current is available regardless of what else is plugged in or turned on.

Calculate Total Resistance in a Parallel Circuit.

Each load (device connected to the circuit) is considered a resistor. To calculate the total resistance (R_t) of a parallel circuit, use 1 as the numerator and the ohms as the denominator and add the fractions together. R_t is the sum.

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

Notice that as more resistors are added, the total resistance goes down. Yes, it is counter-intuitive. That is why the more devices you turn on, the more electricity you use.

1. To determine the resistance of any electrical device, first find its wattage. This is usually listed on a tag or printed on the device somewhere. Amps is the measure of how much electricity if flowing, basically its volume, and Volts is the pressure pushing it.
2. Watts Law states that Watts = Volts x Amps so divide the Watts by Volts to get Amps. All household items (in the United States) are 120 Volts.
3. Now use Ohms Law: Volts = Amps x Ohms Amps = Volts / Ohms Ohms = Volts / Amps

   A 1200 watt blow dryer / 120 volts = 10 amps

   Volts / Amps = Ohms so 120 volts / 10 amps = 12 ohms

   A 60 watt light bulb / 120 volts = .5 amps 120 volts / .5 amps = 240 ohms

   A 150 watt curling iron / 120 volts = 1.25 amps 120 volts / 1.25 amps = 96 ohms

4. When the blow dryer, light bulb, and curling iron are turned on, the total resistance in the parallel circuit is:

$$\frac{1}{Rt} = \frac{1}{12} + \frac{1}{240} + \frac{1}{96}$$

$1/R_t$ = 20/480 + 2/480 + 5/480 = 47/480 Since it is $1/R_t$, invert to 480/47 and divide to get 10.213 ohms. 120 volts / 10.213 ohms = 11.75 amps

Total Amperage is much easier to calculate. They are simply added together. The 10 amp blow dryer with the .5 amp light bulb and the 1.25 amp curling iron will require 11.75 amps.

Have you ever "blown a fuse" or "tripped a breaker." The fuse and circuit breaker are safety devices in your home's electrical system. They shut off the circuit if too much electricity starts to flow. They keep the wires from getting hot and possibly starting a fire. Most fuses and circuit breakers are set at either 10 amps (for small wires) or 15 amps (larger wires). These 3 devices would not "trip" a 15 amp circuit breaker but would "trip" a 10 amp breaker.

5. Calculate the Watts, Amps, and Resistance of electrical devices in your home. Remember, household voltage is always 120 volts.
6. Although it is a different form of electricity, you can use the same equations for electrical circuits in your car. The car, however, uses 12 volts.