Energy & Generators & Motors
A Real World Science Lesson Plan

BACKGROUND:

In WWII electronics were a big deal. Every plane, tank, and boat was filled with switches, coils, and tubes. Although electricity had been discovered much earlier, the 1920s and 1930s were the time when the technology started to catch up to its promise.

In addition, an understanding of the use of the electromagnetic spectrum to send and receive information had grown. The adoption of radio and radar pushed electronics further.

Electricity and magnetism can seem like separate topics, but it is where they relate that a real understanding of each is found. Electricity generates magnetic fields and vice versa. Manipulation of magnetic fields creates electromagnetic waves, and electromagnetic waves can induce a current.

Thus, the innovations of WWII electronics, and the stories of how they were used, are a great way to supplement your electricity and magnetic curriculum.

OBJECTIVES:

- Students will be able to describe the relationship between electricity and magnetism, giving examples of phenomena that connect them.
- Students will be able to identify the parts of a motor and the parts of a generator on a diagram, and explain how they work.
- Students will be able to identify the parts of a radio transmitter and a radio receiver on a diagram and explain how they work.

GRADE LEVEL:

5-8 with enrichment activities for advanced students

STANDARDS:

3rd-5th grades:

- Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form. **NGSS PS3.A** and PS3.B
- Patterns can encode, send, receive and decode information. **NGSS PS4.C**

6th-8th grades:

- Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object. **NGSS PS2.B**
- Waves can be used to transmit digital information. Digitized information is comprised of a pattern of 1s and 0s. **NGSS PS4.C**

TIME REQUIREMENT:

Energy and Generators and Motors will probably take an hour.

My Gal Sal will probably take about half an hour.

MATERIALS:

For **Energy and Generators and Motors** you need supplies for demonstration. These might include:

- Aluminum pipe, copper pipe and neodymium magnets (Lenz effect)
- Hand-Powered generator
- Fan that has been taken apart to show workings
- Coil around screwdriver, battery
- AA Battery, aluminum screw, copper wire, neodymium magnets (homopolar motor)

For **My Gal Sal** you will just need a copy of the handout.

PRIOR KNOWLEDGE:

Students will need to know the basics of electrical circuits before they come to these activities.

INFORMATION FOR TEACHERS:

My Gal Sal is a real plane, and it is on display at the National WWII Museum, in the US Freedom Pavilion: The Boeing Center. Part of one of the original, bent, propellers is on display too.

OUTLINE OF ACTIVITIES:

These activities do not need to be done together.

1. In **Energy and Generators and Motors,** students will learn about the interactions between electricity and magnetism with some demonstrations. They will review power generation, and the the structure of motors and generators. Then they will compare the relationship between electricity and magnetism, and the similarity in structure between motors and generators, and radio transmitters and receivers.
2. In **My Gal Sal** students read about a real situation in which people needed to use electricity to send and receive radio waves, and used a generator to make that electricity.

ASSESSMENT:

Student responses on handouts will provide some data on their understanding of the relationship between electricity and magnetism, and of the mechanisms we use to manipulate them.

EXTENSION/ENRICHMENT:

By adding in more demonstrations, or by having stations or groups use the equipment themselves, you could take this introduction to the concepts further. It's pretty easy to put together a simple telegraph circuit to show how information can be encoded electronically.

Find out more about My Gal Sal and B-17s:
http://www.nationalww2museum.org/us-freedom-pavilion-the-boeing-center/boeing-b-17-flying-fortress.html

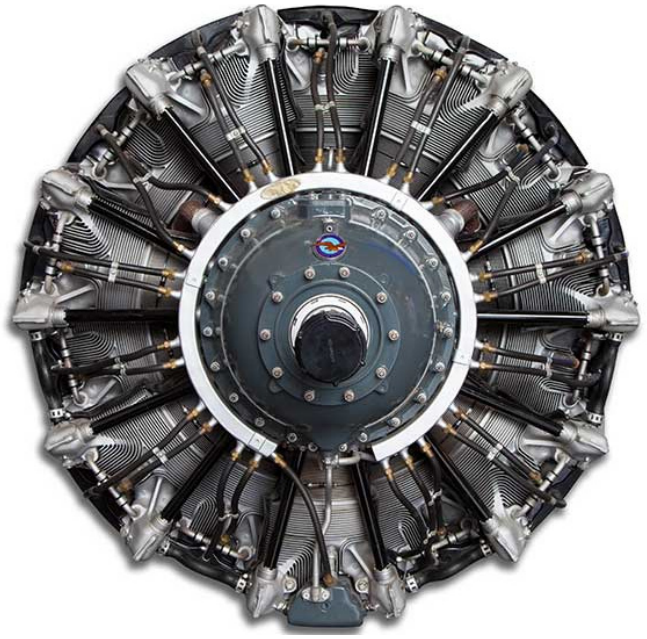
STUDENT HANDOUT

Energy and Generators and Motors

Just look around you to see how much we depend on electricity today. Lights, heating, cooling, cooking—today we often need electricity for all those. Even cars, which run on gasoline, won't work without electricity.

One hundred years ago things were quite different. It's very likely that back then people in your town or city used gas lights, oil lamps, and candles for light. They used wood or coal for heat and cooking. Cooling meant opening the window. Cars were started with a crank, not a battery.

WWII was right at the time that all that changed. Electricity was invented and put to use before then, but it was easier and cheaper to meet energy needs the way people had been doing for centuries than to change. To make all the stuff we needed for the war effort, manufacturers learned all sorts of ways to include fancy electronics. And after the war they learned how to use those fancy electronics to make TVs and home radios, and better cars, and clothes washers and refrigerators.



This is the Pratt & Whitney Twin Wasp R-1830 Radial Engine. This air-cooled engine, which powered planes like the B-24 and the C-47, was the most-produced piston engine in aviation history, with more than 170,000 engines produced over its production span. Piston engines like this one are often used secondarily to produce electricity for the vehicle as well as their primary function of propulsion.

Where does all that electricity come from? And how do we make things that can put it to use? There is one answer to those two questions: we put magnets and circuits together.

When a magnet moves inside a coil of wire (or when a coil of wire moves inside a magnetic field) an electric current is generated in a wire. That's called a generator. A generator generates electricity. You have to be careful what you say here, because you can't make (generate is a fancy word for make) energy. You can only change energy from one form to another. In the case of a generator it takes movement of a wire or magnet (mechanical energy) and turns it into a current (mechanical energy).

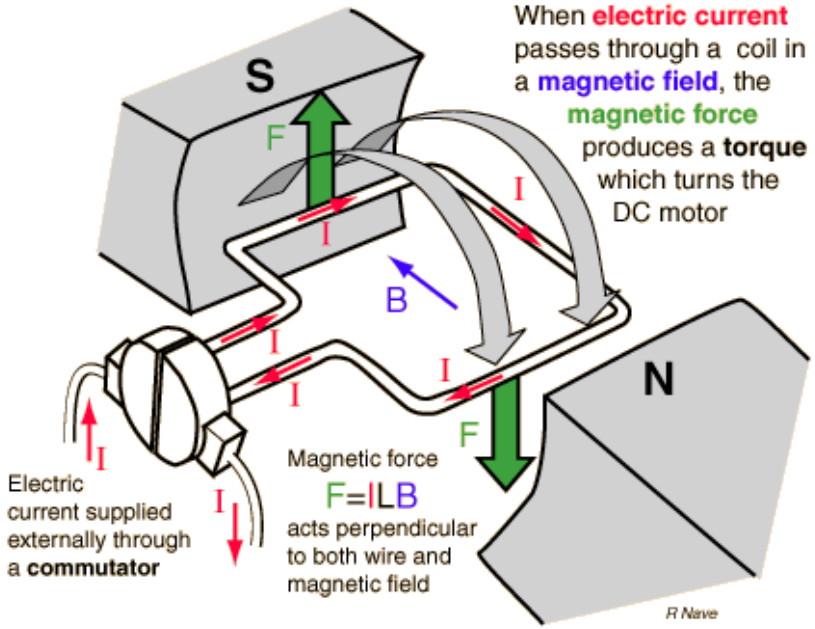
When a magnet is around a wire carrying current, it will move. Or, if the magnet is stuck in place, the wire carrying the current inside the magnet will move. This is called a motor. A motor turns electric current (electrical energy) into motion (mechanical) energy.

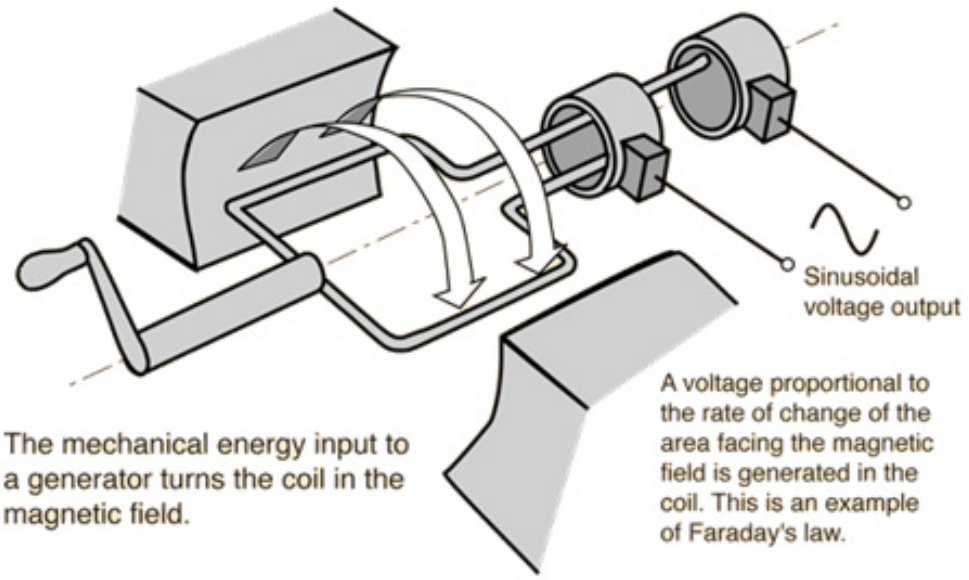
STUDENT HANDOUT

Energy and Generators and Motors

So a generator is a motor going backwards and a motor is a generator going backwards:

Why does this happen? Because an electrical current generates a magnetic field. If you held a compass near a wire carrying current, you'd see the compass point in the direction of the current. If the wire is made into a coil, the magnetic field is even stronger. This is why there are so many coils inside of fancy electronic devices.





Take a look at these diagrams of a motor and a generator. Put notes on them that explain how they work.

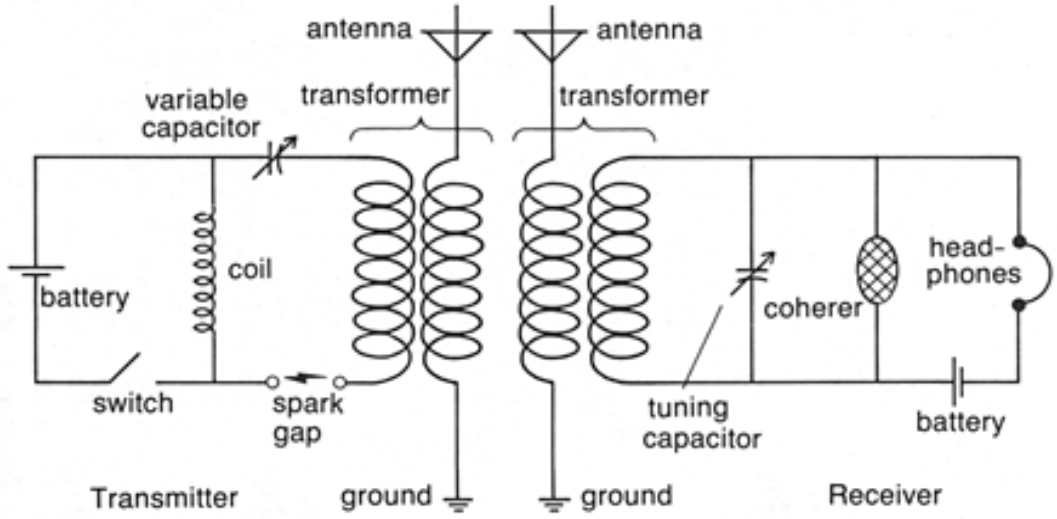
STUDENT HANDOUT

Energy and Generators and Motors

Electrical currents make magnetic fields that you can't see. They make something else you can't see either—they make electromagnetic waves. The most common places you can see these in your house are in microwave ovens. Your cell phone makes electromagnetic waves too, but its parts are too small to see easily.

A microwave oven has two strong magnets that it spins around a bunch of wires. The magnets and wires together cause a changing current that makes a pattern of changing magnetic fields. This changing field sends out electromagnetic waves.

Microwaves were first used in WWII, but not for cooking. They were used to send signals for communication and radar. A microwave oven is a form of radio transmitter (but its waves are tuned to cook not send signals). A radio transmitter and a radio receiver are very similar, just like motors and generators are similar.



Make notes on the diagram to explain how they work? How are the two devices similar? How are they different?

STUDENT HANDOUT

Energy and Generators and Motors

You're going to see some demonstrations of how magnets and current interact. Draw diagrams of the demonstrations and put explanations with them in the space below:

Demonstration One:

Demonstration Two:

Demonstration Three:

STUDENT HANDOUT

My Gal Sal

In late June of 1942 the US was sending troops to Europe as part of a buildup of forces. B-17s, designed as bombers, were being used to ferry troops. The planes would take off from Canada, land and refuel in Greenland, land and refuel in Iceland, before arriving in Britain.

On June 27th, 13 B-17s took off from Labrador heading to Greenland. They encountered very rough weather over the North Atlantic, and 5 planes returned to Labrador. Five planes made it safely to the airbase in Greenland, and 3 had to make emergency landings on the Greenland ice sheet. The crew of one of those planes, which they had nicknamed My Gal Sal, made a pretty smooth landing. The only serious damage was to the propellers of the plane. These were all bent and twisted and kept the engines from being used.

The crew needed to radio for help, or they would remain stranded on the ice sheet. Unfortunately they had to run at least one engine to turn the generator that provided the electricity for the radio transmitter and receiver. It took a whole day, but the crew were able to use tools from the plane to cut off the bent parts of one propeller so that they could power up a single engine. They got the radio going and made contact with the airbase.

My Gal Sal in the Museum's US Freedom Pavilion: The Boeing Center.

There was nowhere to make a safe landing on the ice near their plane, so the crew camped there for 17 days while a rescue was organized. After that they had to hike 25 miles to a frozen lake, where there was enough flat ice for a rescue plane to land. Two weeks later 6 P-38 fighter planes were forced down in the same area of the Greenland ice. A month later a crew on dogsleds returned to retrieve the Norden bombsight from the nose of My Gal Sal.

STUDENT HANDOUT

My Gal Sal

After that no one saw the plane until 1964. A US Air Force Reconnaissance plane spotted it, now lying upside down on the ice. Imagine the storm that would flip over a B-17!

In 1995 My Gal Sal was recovered from the ice, and in 2000 a restoration of it began in Cincinnati, OH. It now hangs in The National WWII Museum's collection of planes, after being shipped in pieces and reassembled.

B-17 "Flying Fortress" Facts:

- First produced in 1941
- 512 were built
- Crew of 10 men
- 104 feet in wingspan, 74 feet in length
- 4 engines, 1,000 HP each
- Maximum speed of 318 mph, cruising speed 226 mph
- Maximum range of 3,200 miles
- Load of 4,200 pounds

B-17 bomber takes off from airfied in Italy,, 1944. The National WWII Museum, 2011.160.075.