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## World's Simplest Motor

SS-11

### First, some background:

By definition, a motor is:

**A rotating machine that transforms electrical energy into mechanical energy.**  
(Merriam-Webster.com)

Electric motors convert the electric energy from an AC (house electric lines in the US carry AC, or Alternating Current) or DC power source (the electricity produced by solar cells, batteries, and other sources, DC or Direct Current, is also how home electricity is delivered in Europe and many other parts of the world) to mechanical energy.

This discussion and experimentation relies on the student having at least minimal understanding of several concepts, including:

- Energy Transformation
- Magnetic Forces
- Electrical Currents

Use these short video clips to explain magnetism, magnetic forces, electric currents, and motors. NeoK12 has free explanations, games and quizzes about magnetic fields and electricity, and more at the upper elementary/middle grades level of understanding.

View the ***What is the magnetic field*** video clip (2:29 minutes) at:

<http://www.neok12.com/php/watch.php?v=zX4752067171765e67545d45&t=Magnetism>

Try the experiment to view the magnetic field lines seen on the video. You will need white paper, iron filings, and several different magnets for each group. Make sure to record your findings and to draw pictures of what you observe in your science notebooks!

View the ***How does electricity create a magnet*** video clip (4:57 minutes) at:

<http://www.neok12.com/php/watch.php?v=zX57555a4f5f0b606e625063&t=Magnetism>

Try to create your own electromagnet as described in the video. You will need 20-30 staples, a piece of paper, a length of fine copper wire, and several batteries for each group. Make sure to record your data and findings and to draw pictures of what you observe in your science notebooks!

**So, how do motors work?** The transformation of electrical energy to mechanical energy is best seen in a short video such as NeoK12's 2:20 minute video about ***How to build a simple motor, and how it works*** at <http://www.neok12.com/php/watch.php?v=zX5b4c696f007c5c7d525a6b&t=How-It-Works>



# NGSS Correlations

The World's Simplest Motor and these lesson ideas will support your students' understanding of these Next Generation Science Standards (NGSS):

## Elementary

### K-2-ETS1-1

Students can use the World's Simplest Motor to ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

### 3-PS2-3

Students can use the World's Simplest Motor to ask questions to determine cause and effects relationships of electric or magnetic interactions between two objects not in contact with each other.

### 4-PS3-2

Students can use the World's Simplest Motor to make observation to provide evidence that energy can be transferred from place to place via electric currents.

## Middle School

### MS-PS2-3

Students can use the World's Simplest Motor to ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

### MS-PS2-5

Students can use the World's Simplest Motor to conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

### MS-PS3-5

Students can use the World's Simplest Motor to construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.

## High School

### HS-PS2-5

Students can use the World's Simplest Motor to plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

### HS-PS3-2

Students can use the World's Simplest Motor to develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.



**In the Take Apart Lab, devices that are disassembled could be evaluated using the Engineering Design standards:**

### MS-ETS1-2

Evaluate complete design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

### MS-ETS1-3

Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. (especially if several different types of machines that do a particular job are disassembled)

### HS-PS3-2

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.

# Building a Motor

## 1. Define “Motor”

First discuss the definitions of the following motor parts. Students will use these cards after they build their simple motor.

<p><b>Motor</b> A rotating machine that transforms electrical energy into mechanical energy.</p>	<p><b>Armature (or rotor)</b> The moving part of the motor, usually with windings of wire in coils. This part becomes the electromagnet.</p> <p><i>** “Armature” comes from the same word root as “Arm.” Does the armature look kind of like an arm?</i></p>
<p><b>Power Supply</b> An AC (alternating current, like the electricity from your household plugs) or DC (direct current, like the electricity from a solar cell, or dry cell “batteries”).</p>	<p><b>Field Magnet</b> A magnet with a “North” and “South” pole that creates a magnetic force.</p>
<p><b>Axle</b> Mechanical energy from the motor makes this part that looks like a stick spin to do work.</p> <p><i>** Cars have axles that connect the wheels. Do you think that car axles have something to do with motors?</i></p>	<p><b>Commutator and Brushes</b> Attached to the axle, the commutator lets the electric field of the electric current “flip” changing the direction that the electrons flow.</p> <p>Brushes are the metal or carbon connections between the commutator and the armature. These let the current flow from the power source to the electromagnet/rotor.</p> <p><i>** When motors were first made, brushes really were like what we think of as a “brush,” but these wore out too quickly, so they were changed to solid or mesh surfaces, instead of brush-like fingers!</i></p>
<p><b>Stator</b> The part of the motor that stays still, or stationary. The magnets are usually in this part, but the wire winding might be instead.</p>	

## 2. Build the “World’s Simplest Motor.”

## 3. Identify the parts of the World’s Simplest Motor using the word cards above.

# Building a Motor

continued

## 4. Look for Motors

- a. What is the job of a motor? It converts electricity to mechanical energy to make something move (and to do work).
- b. Name some different motors—think about things that are plugged in, or use batteries, that make something move. Those movements are caused by motors.
- c. What motors did you use today?  
*This list might include many things, such as water pumps, electric toothbrushes, clocks, toasters, microwave ovens, hair dryers, vehicles, elevators, computers and printers, etc.*
- d. Search the classroom, school, home for other examples of motors  
*After discussing different things with motors, and identifying the motors in the classroom, this could be a scavenger hunt in the school. It could also be a take-home assignment. Have students set up their own search list paper, heading the paper with the definition of a motor and some examples. (This will help clarify for parents what the student is looking for!)*

## Motors found in most schools (adapted from Yahoo! Answers)

1. Heating fans (HVAC heater for rooms has 2-3 motors—exhaust, ventilation at least).
2. Air conditioners have several; ventilation fans (moving cold air to rooms), compressor (moves coolant around).
3. Kitchens have many: food slicer, mixer, blender, coffee makers, etc.
4. Vending machines (to move product and to keep drinks cold).
5. The flagpole, if it is automated.
6. Roof vents are often motorized.
7. Copy machines use motors to move paper.
8. Printers use motors to move paper.
9. Computers have cooling fans for the CPU.
10. Hard drives have electric motors.
11. The bathroom has a variety of motors: in the fan air dryers there is one, in the automated towel dispensers or faucets are others.
12. The maintenance department usually has a drill, saws-all, and circular saw. Each of these tools is a motor.
13. The wood shop has a band saw, planer, belt sander, table saw, and handheld sander.
14. The metal shop usually has a circular grinder, air compressor and pneumatic pumps driven by motors.
15. Every analog clock on the wall has a motor.



# Building a Motor

continued

## 5. Do a Take-Apart Lab

In a Take-Apart Lab, students have the opportunity to disassemble common household items. Besides being fun, this lets kids discover the inner mystery of machines, identify how that machine works, and in this case, identify where motors are used to help that machine do its task.

**For the Take-Apart Lab, there are several important cautions.**

1. Items have sharp edges. So do tools!
2. Do not break or bend something to take it apart. Use screws, tabs or other fastenings.
3. Use a tool for its intended purpose. Screwdrivers are not hammers! Students should be instructed in the correct use of tools!
4. Have soap and water and Band-Aids available for any small cuts and scrapes.
5. Do not take apart anything that is dangerous, including items on the following list:

### What not to take apart:

**DO NOT** take apart TV sets or computer monitors! Even when unplugged, they can have high voltages stored in the capacitor.

**DO NOT** take apart smoke detectors. Many use a radioactive element inside.

**DO NOT** take apart items with oil filled capacitors (may have PCB contaminated oil) such as: air conditioners, copy machines, dehumidifiers, fluorescent light ballasts, mercury vapor lamps, microwave ovens. **See resource note at the end of this lesson to help identify capacitors.**

**DO NOT** take apart oil-filled space or portable heaters. The issue with these items is not the presence of a PCB capacitor, but the presence of PCBs in the actual oil inside of the heater. This condition is present in a very few manufacturers' products, however, PCB levels present in these can be quite serious.

**DO NOT** take apart submersible well pumps.

**DO NOT** take apart air conditioners or refrigerators with high pressure Freon.

**DO NOT** take apart wall thermostats, since many older models of dial thermostats contain mercury.

# Building a Motor

continued

## Plan ahead for the Take Apart Lab

Send a request home to families and other staff to collect donated broken or old appliances, toys or other items. Also, request the loan of tools for each team to use. (Tools can be marked with the owner's name.) Tools should include the following: several screwdrivers of different sizes, including straight and Philips head, small Allen key wrenches, wrenches and pliers of various sizes and types including needle-nosed pliers.

It is advisable to **recruit other adults to help provide supervision** (and make suggestions) for teams.

Each team (2-3 students) should have:

- One approved appliance
  - A tool kit
  - Safety glasses for each team member
  - Non-latex gloves for each team member
  - A cardboard surface or drop cloth to work on
  - A bowl or other container to collect small pieces such as screws
1. Identify your appliance. What does it do? How do you think it works? Do you think there are motors in this appliance? Record the answers to these questions in your science notebook before you start to disassemble it!
  2. Work as a team to disassemble your appliance. After you get the cover off, try to identify how the appliance works. Record your observations and make sketches in your science notebook.
  3. As you work on disassembly, make sure to discuss each step with the team and to share jobs, including recording your procedure and findings.
  4. What motors did you find? Use the motor parts identification cards to identify the parts of the motors.
  5. As a class, discuss the group findings:
    - a. What types of appliances were disassembled?
    - b. What is the job of those appliances?
    - c. What appliances have moving parts?
    - d. What motors were found?
    - e. Were those motors the source of energy for the moving parts?

# Building a Motor

continued

## Identification of Capacitors:

(Source: <http://www.ct.gov/deep/cwp/view.asp?A=2710&Q=324258>)

### A. Starting Capacitors

Starting or electrolytic capacitors are used to assist a single-phase electric motor in starting. These components are used for short periods of time during operation of the motor. Consequently, starting capacitors do not need to dissipate heat and are, therefore, primarily dry capacitors. Starting capacitors are most easily identified by black plastic casing or outer shell. If the capacitor is dry, the casing is not hermetically sealed or totally enclosed, but generally contains a porous plug at one end.

### B. Running Capacitors

Running or oil-filled capacitors are designed to stay in a motor circuit for the entire cycle of operation. The oil helps to dissipate the heat in the capacitor during operation and maximizes the running efficiency of a motor. Running capacitors are identified by rectangular or oval metal casings. An oil-filled capacitor manufactured after 1979 may have "NO PCBs" stamped on its casing. These are filled with oil which does not contain PCBs and may be treated as a starting capacitor for disposal purposes.

## Resources:

How Stuff Works "How Electric Motors Work"

<http://electronics.howstuffworks.com/motor1.htm>

NeoK12's two-minute video about how to build a simple motor, and how it works

<http://www.neok12.com/video/How-It-Works/zX5b4c696f007c5c7d525a6b.htm>

(plus a lot of other kid-level How and Why type videos)

Guide for removal, storage, and disposal of PCB small capacitors

<http://www.ct.gov/deep/cwp/view.asp?A=2710&Q=324258>

50 Dangerous Things: Deconstruct an Appliance

<http://theriskykids.com/2012/06/50-dangerous-things-deconstruct-an-appliance/>



# Take Your Lesson Further

As science teachers ourselves, we know how much effort goes into preparing lessons. For us, “*Teachers Serving Teachers*” isn’t just a slogan—it’s our promise to you!

Please visit our website  
for more lesson ideas:

[TeacherSource.com/lessons](http://TeacherSource.com/lessons)

Check our blog for classroom-tested  
teaching plans on dozens of topics:

<http://blog.TeacherSource.com>

To extend your lesson, consider these Educational Innovations products:

## Homo Motor Kit (KIT-700)

Introduce your students to one of the simplest devices, the homopolar or ‘one pole’ electric motor. Credited to Michael Faraday, it does not involve the polarity change of more complex motors. Includes instructions to make three different styles of HomoMotors, pinwheel, spiral and butterfly. Students build the motor, make it run, and can then break it down to make a different one. They can even design and build their own variations.



## Hand Cranked Generator (GEN-100)



This hand-held crank generator produces up to 12 volts of DC electricity. It can be connected to an external circuit or, with a small bulb (included) used independently as a flashlight. Housed in tough transparent plastic, all of the components can be easily observed. In addition, other devices can be easily connected to the black and red screw terminals on the front of the generator without the need for any special adapter that could be quickly lost.

## Transparent Alternator Kit (OHM-150)

Our ingenious Transparent Alternator Kit has been designed to take the mystery out of how electricity is produced. This little device can be assembled easily in 20 minutes without tools. That's when the discoveries begin! What can you power with your alternator? How is electricity generated from a magnet and some copper wire? A wonderful hands-on introduction to electricity. With modifications, you can produce enough electricity to charge a cell phone! Once built, this alternator can be unwound, disassembled, and rebuilt over and over again.



## Energy Tube (OHM-350)



Safely demonstrate open and closed series circuits without any danger of electric shocks! When the tube is 'turned on,' the red, green, and blue lights light up and it makes a funny buzzing sound. Turning the tube on is the fun part - just touch the metal ends with both hands. Your body forms the conducting material that bridges the gap between the two metal strips and closes the circuit!