CSUVENTURES
Innovation at Work

College of Natural Sciences
Education & Outreach Center

Colorado State University

Regenerate!

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Wasted Energy

Energy cannot be destroyed. It can only be converted into another form or transferred to another thing. We all know that it takes energy to get a car to move, so what happens to that energy when we get the car to slow down and stop?

Do This: Put the temperature sensitive film on the table with the label face down. Roll the wheels of the model car over it.

Science Notebook: Write down what you observe in your science notebook.

Do This: Put the Alkaline AA battery in the model car and turn it on. Hold the temperature sensitive film in place and gently try to slow down the back wheel by pressing it down on the film.

Science Notebook: Write down what you observe in your science notebook.

Brakes in most cars and trucks convert the vehicle's kinetic energy into heat energy as the brake shoes rub on the disk or drum attached to the wheel. This heat comes from friction, which you can measure using the temperature sensitive film.

These kinds of brakes have been working well for a hundred years. However, now that we are running low on good sources of fuel, it is a shame to waste that good kinetic energy on heat that dissipates into the air. We need a way to slow down a car by converting its kinetic energy into useful *potential* energy.

There are a few ways to do that:

- We could use the wheels to wind up a spring or rubber band.
- We could use the wheels to spin up a heavy rotating disc called a flywheel.
- We could use the wheels to charge a battery.

The last option is the approach that new hybrid vehicles use, so we will explore this further.

Subatomic Particles

To charge a battery, you need to pump electrons back through the battery the opposite way they flow when the battery is being used.

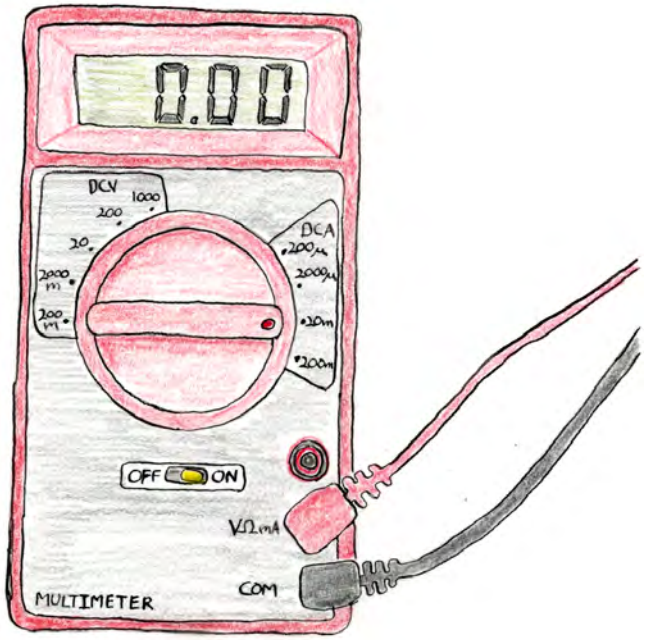
Electrons are what we call subatomic particles. They orbit the atom's nucleus which contains protons and neutrons. Atoms of metals are unique in that the electrons are not tightly attracted to the nucleus. Electrons in metals are free to roam from one atom to another.

A copper wire is made up of zillions of copper atoms with electrons that can move freely between them. The electrons in a piece of copper wire that is not connected to anything are all moving in random directions. If we can make the electrons all move in the same direction, then we have electricity!

Let's move some electrons!

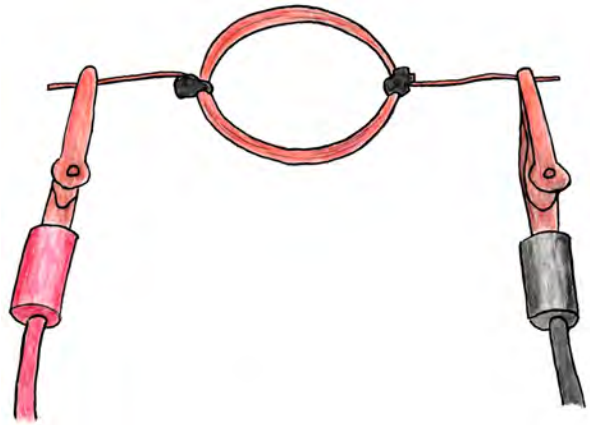
Step 1

The multimeter allows us to measure the flow of electrons in wire. To set up your multimeter, rotate the big round switch to '20m' in the 'DCA' section. Plug the black cable into the COM jack and the red cable into the VΩmA jack as shown in this diagram. Turn it on.



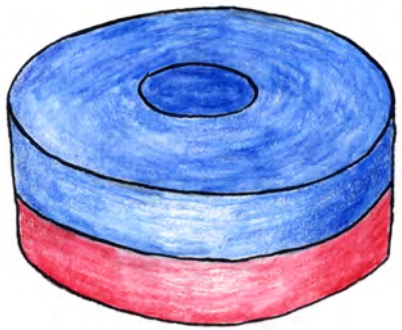
Step 2

Clip the multimeter cables to each end of the wire coil like this:



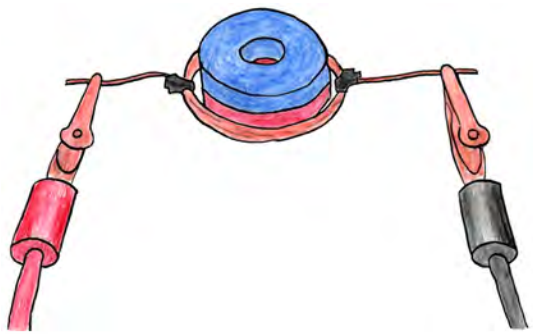
Step 3

Stick a red and blue magnet together like this:



Step 4

Place the coil flat on the table and place the two magnets in the center of the coil. Watch the meter readout as you quickly lift the magnets up and away from the coil.



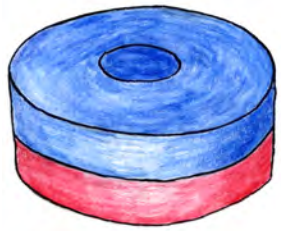
Try flipping the stack of magnets over. What happens?

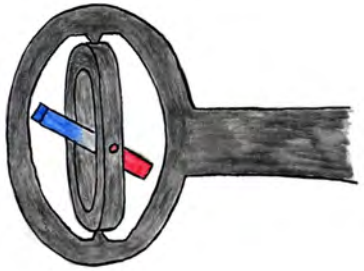
How about leaving the magnets on the table and moving the coil instead?

Science Notebook: Draw a diagram of your experiment in your science notebook. Describe what happens.

Congratulations! You have just generated a tiny bit of electricity! Electricity and magnetism are linked in a fascinating way. To better understand what is going on, it helps to know that the magnets have an invisible magnetic field around them.

Do this: Use the Magnaprobe to see how far away from the magnets the field reaches, and figure out what shape the field has.





Please be gentle with the Magnaprobe. It is delicate.

Science Notebook: In your science notebook, draw a picture of the shape of the magnetic field surrounding the magnets.

The magnetic field helps to move the electrons in the copper wire, even though copper is non-magnetic. If you move the magnetic field in one direction, the electrons go with it. Move the magnetic field in the other direction and they switch direction instantaneously. Pretty cool, eh?

Generating More Electricity

Now that we know how to make electrons flow through wire, we need a way to produce a useable amount of electricity. One good way is to use a stronger magnet and/or more loops of wire.

Do this: Stack two blue magnets on top of two red magnets and see if you can generate twice as much electricity as you did before.

An even better way is to quickly spin either the magnet or the coil of wire, but not both.

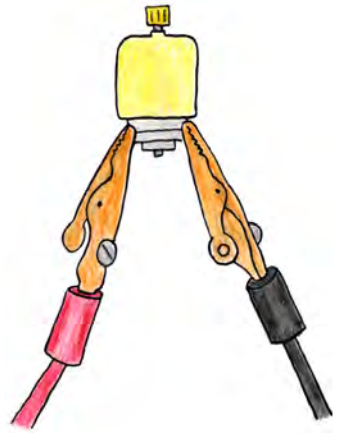
Do this: Without opening the jar, use the Magnaprobe to investigate the three pieces in the plastic jar.

Science Notebook: Draw a picture of the pieces you see. Write down what you speculate their

purpose is.

Step 1

Find the other one of these devices in your kit that has not been taken apart. Carefully hook it up to your multimeter. Make sure that the alligator clips only touch the copper connector tabs and not the metal case.



Step 2

Spin the gear on the shaft clockwise and then counter clockwise.

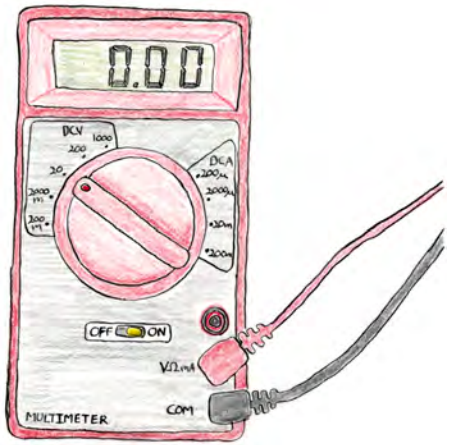
Science Notebook: What do you notice? Are you able to generate more electrical current than you did manually? Why is it a positive number one direction and a negative number the other direction?

Generating Even More Electricity

The wire and magnet device is called a generator when something actively turns the shaft. Let's try spinning it even faster.

Step 1

Switch the big round selector switch on the multimeter to '20' in the 'DCV' section. The readout will now report Volts, which is used to express electrical potential.



Step 2

Hold the model car upside down and turn it on.

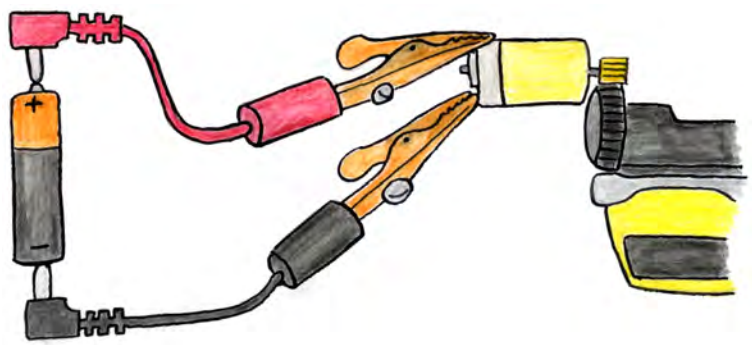
Step 3

With the generator still connected to the multimeter, allow one of the rear wheels to spin the gear on the shaft of the generator.

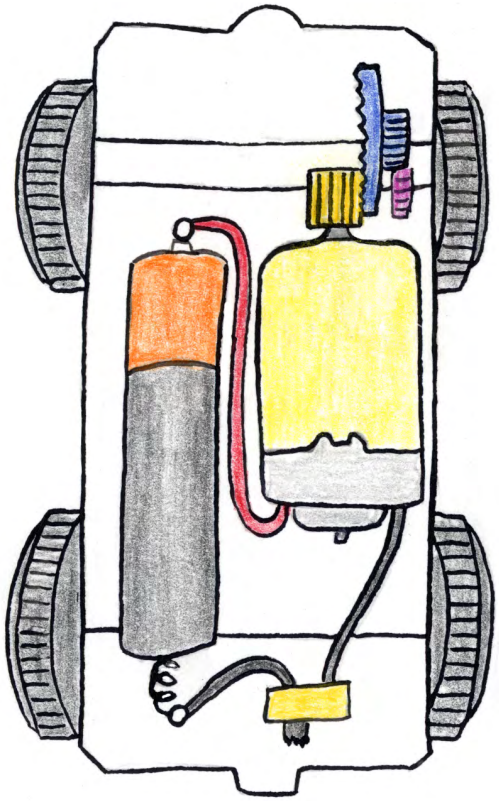
Science Notebook: What voltage do you get and how stable is it? How do you make it positive or negative?

Now, just for kicks, let's see what happens when you hook up the generator to the Alkaline AA battery that is in the car (Note, the rechargeable battery in your kit is dead).

Do this: Hook up the generator like this:



Wow, so this simple little device generates electricity when you turn the shaft *or* acts as a motor when you supply it with electricity. This model car has this very same device inside. Here is a drawing of what the inside of this car looks like.



Hybrid Vehicles

The word 'hybrid' means a combination of two different things. In our case, a gasoline vehicle and an electric vehicle. These new vehicles have a computer that decides which source of energy to use based on the driving situation.

But it gets better than that! Remember at the beginning when we saw how energy was wasted when brakes are applied? We then set out to find a way to slow the car down by converting the kinetic energy of motion to potential energy stored in a battery.

Now we know that if we use the wheels to turn the electric motor's shaft, it will charge the batteries.

Step 1

Put the dead rechargeable AA battery into the model car and turn the car on. **Note:** if the wheels begin to turn, let the battery run down before moving on to the next step.

Step 2

Roll the car along the table without letting go. You are now charging the battery!

Science Notebook: Why can't we design a self sufficient car with an electric motor powered by batteries which are charged by a generator that is always connected to the wheels?

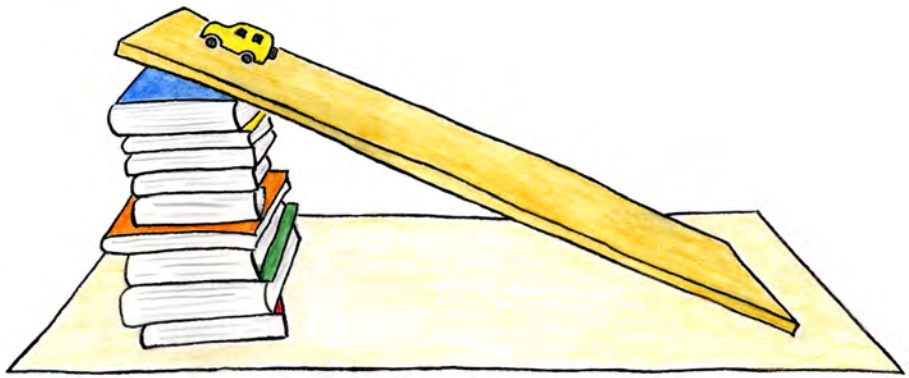
This is a tough question. Here is a hint! Recall the coil of wire and the magnets. The copper wire is non-magnetic, but the electrons within the wire are influenced by the magnetic field of the magnet. If those electrons are not used, the shaft will spin freely. However, if you use the electrons to charge a battery or power a headlight, then the shaft of the generator gets harder to turn!

Step 1

With the dead rechargeable battery in the model car that is turned 'Off', let it roll down a ramp that is at least 1 meter long. **Tip:** it works better to roll the car backwards.

Step 2

Repeat Step 1 with the switch on the car turned 'On'. Now the electrons are charging the battery.



Science Notebook: What difference do you observe? Describe how you can slow a car down by charging a battery.

This system is called '*regenerative braking*' and allows the car to use less fuel. Transportation accounts for 80% of our oil use.

Science Notebook: How does charging a battery allow the car to use less fossil fuel?

This principle also affects wind turbines. On a really windy day, you may see a turbine spinning slowly. This is because the electricity that the generator is producing is being heavily used to power homes and buildings. The wind turbines are *working* hard to deliver power. In fact, the word 'work' has a specific scientific meaning. It is a measure of how much energy is transferred from one system to another.

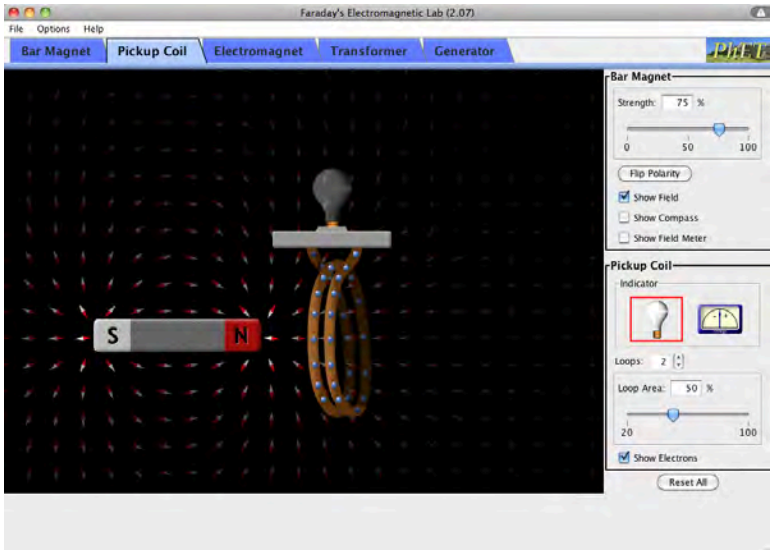
Do This:
Turn off the multimeter and remove the battery from the model car. Put everything back in the box as you found it.

Simulations

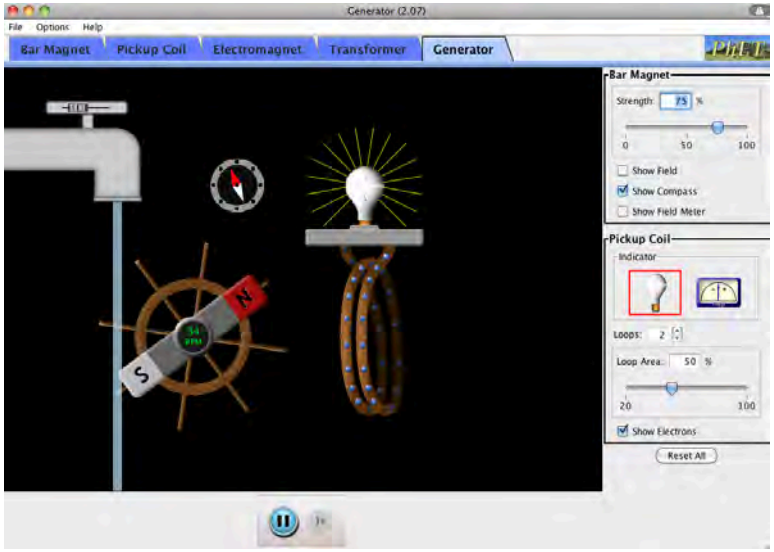
We encourage you to explore the following three online simulations that might help you better understand the concepts we have been studying. The first simulation shows you the difference between kinetic, potential and thermal energy.
http://phet.colorado.edu

Energy Skate Park

The next one to try is called Faraday Electromagnetics Lab. Click on the 'Pickup Coil" tab.



The final one is on the ‘Generator’ tab.



Science Notebook: Write about what you learned by using these computer simulations.

Interview with Noel Marshall

Was there a particular moment when you began thinking about becoming an engineer?

The moment in high school when I started thinking about becoming an engineer was the same moment when I realized I was talented in mathematics. I had always had a strong interest in the automotive industry, so combining that with mathematics, it only made sense to pursue a higher education in the engineering field.

Who was you favorite teacher in middle school?

My favorite teacher taught me Algebra 2 and his name was Mr. David Arneson. He was an exceptional teacher and football coach, but he had a

unique way of helping students understand mathematics. His approach was more towards following the rules of algebra rather than the theory and why the rules existed. Whether or not this is the "right" approach, it helped me excel rapidly in his class. This is when I found my love for mathematics.

What classes did you take in high school that helped you get into college?

During my senior year of high school we earned some privileges and responsibilities including the freedom to choose our own electives. Most students opted for a "free" period or a gym class to make their last year a little easier. Nerdy as it may be, I chose math courses for my electives. Taking pre-calculus and receiving an A also earned me 4 credit hours of mathematics at the local university. This was not only "free" but also started off my college career with a 4.0 GPA.

Why did you choose to go to CSU?

I think CSU chose me. I had applied to numerous schools and was eventually accepted to CU Boul-

der. CU is where I was going to go, although I wasn't that excited. At the last minute I was told about CSU and how they had a reputable engineering program so I applied. I was accepted and now had a decision to make. Once I took a tour of the campus and got a taste of the city of Fort Collins I was sold!

What are you working on in the lab?

Our team of senior engineering students is working on another type of hybrid vehicle called a fuel cell plug-in hybrid car. A fuel cell plug-in hybrid car utilizes the same technology as a traditional hybrid vehicle with one major difference: a plug-in car uses the output of a fuel cell to power the motor and charge the car's battery. In a fuel cell, hydrogen and oxygen are combined in an electrochemical reaction that creates electricity with only water as a byproduct. For this reason and because the car doesn't run on gasoline, fuel cell car do not pollute the air.

What do you plan on doing for your career?

I hope to find my way into an alternative and/or renewable energy career.

$1.49

Materials Needed

Multimeter
Four round magnets
Magnaprobe
Coil of wire
Jar of parts
Gear motor/generator
Temperature sensitive film
Model electric car
Alkaline AA Battery
Rechargeable AA battery (Uncharged)
Internet access

Visit www.cns-eoc.colostate.edu/regenerate.html
for supporting materials.

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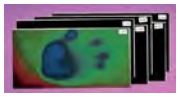
Regenerate! Kit **Parts List for each Kit**

	Qt	Item	Part/Product No. & 2012 Price (U.S. $)	Vendor
	1	Toy car (Motorized Mobiles)	G02397 $7.99/2 http://www.intplay.com/productdetails.aspx?pid=3988	international playthings
	1	Magna probe, Mark II	44702 $16.95/1	Indigo.com
	2 2	Blue magnets Red magnets	3052375 $4.95/12 (4 red, 4 blue, 4 yellow)	Scientificsonline.com http://www.scientificsonline.com/
	1	1.5-3 V Metal gear motor	273-258 $3.39/1	Radio Shack http://www.radioshack.com/home/index.jsp
	1	DC motor (take apart to show parts)	P8-8375 $20/10	Arbor Scientific
	1	25-30 Temp film (cut to1.5"sq) Temperature Sensitive Liquid Crystal Sheets	30723-74 $24.95/12" x 12" sheet	Scientificsonline.com http://www.scientificsonline.com/
	1	Multimeter (w/Copper aliigator clip: note you will need to attached copper clip to wire leads after removing the lead probes typical supplied with multimeters)	~$4-7	Harbor Freight http://www.harborfreight.com/#
	1	Black Copper clip	82R5328 $0.94/1	Newark.com Manufacturer (Silvertronic) Part No: 502000C_B
	1	Red Copper clip	82R5330 $0.94/1	Newark.com Manufacturer (Silvertronic) Part No: 502000C_R
		Enamel Magnet Wire, Gauge: 22, Approximate Length: 125 feet, Temperature Range: -30-+80 DegC, Insulation: Enamel, Used for making custom coils, transformers etc	05H7640 $10.19/125 ft	Newark.com
	2	4" zipties (to wrap coil with)		Harbor Freight/any hardware store
	1	AA alkaline battery		Harbor Freight/any hardware store
	1	AA NiMH rechargable		Harbor Freight /any hardware store
	1	popsicle stick (to assist with magnet exploration)		any art supply store
	1	white box (9"x6-1/4"x2) -corrugated literature mailers	21137887 $40.99/50 (Manfr # MFL962)	Office Max http://www.officemax.com/