Energy: Electricity, Heat & Light

The properties of electricity will be discussed and demonstrated with a Tesla coil and a simple generator allowing the students to turn kinetic energy into electricity. Chemical reactions to make electricity, heat and light will also be performed. The ability to convert one form of energy into another will be discussed.

Stuff:

* **insulated container (small ice chest) for Dry Ice (*you provide*)**
* **large aluminum serving tray (or equivalent) for burning Mg in Dry Ice (*you provide*)**
* **one pair of light cloth or leather gloves for handling the Dry Ice (*you provide*)**
* **pencil, metal rod, or butter knife (not plastic or cardboard) (*you provide*)**

Tesla Coil (*we provide* – ***you must return!!***)
Extension cord (*we provide* – ***you must return!!***)
a big screw driver with a plastic or rubber handle (*we provide* – ***you must return!!***)
Generator powered flashlight (*we provide* – ***you must return!!***)
Propane Torch (*we provide* – ***you must return!!***)
35 plastic safety glasses (*we provide* – ***you must return!!***)
2 Chemical Heat Packs (*we provide*)
2 Chemical Cold Packs (*we provide*)
4 Chemical Light Sticks (*we provide*)
24 g Mg chips (*we provide*)
Dry Ice (*we provide – but you need to bring an insulated container to put it in*)

General SAFETY notes: You are representing LSU. Please be professional and safety conscious. 90% of safety is using good common sense and being cautious. Wear safety glasses when working with chemicals. ***It is a good idea to practice the experiment before attempting it as a class demonstration. You will gain confidence and appear more professional to your audience.*** The Tesla Coil generates high voltage, but very low current (amps). Please turn it down to a lower setting (the twist knob on the bottom) when shocking students. One of the safest places to shock the students is on their arm or back of their hand (fewer nerve endings). You will note that repeated shocks to the same area of the skin does cause a reddening of the skin – so try to move the shock point around a little when shocking the same student more than once. Do NOT shock any students who do NOT want to be shocked. Do NOT let students play with the Tesla Coil! The propane torch should not be left in a hot car. Keep it away from students. Turn it off when not in use. ***The burning Mg in dry ice should be performed outside.*** Keep students back about 10 feet from the experiment because small white-hot Mg sparks sometimes fly out of the burning mixture. The "smoke" produced is MgO and is generally non-toxic – although it may annoy students that are sensitive to fine dust. They should wear safety glasses for this experiment. The chemicals in the hot and cold packs and light sticks are generally non-toxic and safe to dispose of in a trash can – but do not let the students open the light sticks or hot/cold packs, it will make a big mess.

Initial Discussion on Types of Energy: Ask the students to name different types of energy and make a list of their correct responses on the blackboard. Explain any incorrect answers as you go along. Prompt them (or give hints) for the types of energy they don't come up with. A list of some common kinds of energies is as follows:

Heat	Electricity	Kinetic	Potential	Electromagnetic
Nuclear	Sound	Magnetic	Chemical	Light

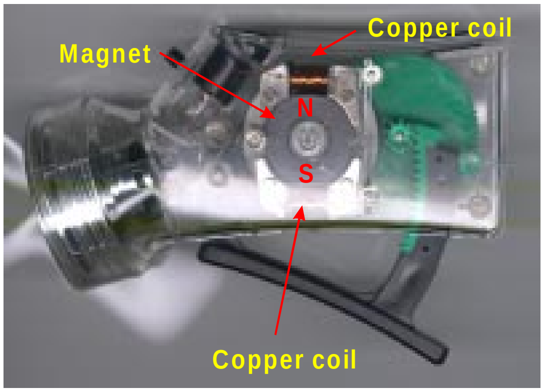
Light is a sub-set of electromagnetic energy, which also includes radio waves up through X-rays and some aspects of magnetic energy. Chemical and nuclear energy is, in some ways, a subset of potential energy (stored energy waiting to be released in some fashion). Sound can be considered a subset of Kinetic energy. But you don't have to go into details on these fine points. You will probably have to explain kinetic, potential, and electromagnetic energy to them. Give some examples. Discuss how one form of energy can be converted into another under the proper circumstances (e.g., light shining on a solar cell to generate electricity). We are generally interested in using one or more of these forms of energy to perform WORK. Work is the movement of objects. One always needs energy to perform work.

Electricity: Plug in the Tesla Coil and have it ready to go. Start off by asking what the voltage in a standard electrical outlet is (110 volts). Ask how many students would want to get shocked by 110 V (you might get a few cocky students). Now ask how many would like to get shocked by 20,000 V!! Turn on the Tesla Coil (the round knob on the bottom) and shock the tip of the screwdriver. Note that you will feel a small to medium shock as you do this, but if you keep your hand away from the metal shaft of the screwdriver you should not get any big shocks. The electricity is flowing through you, but it is being diffused out by the plastic handle so you don't feel any big shocks. Turning the classroom lights off will allow the students to see the spark better. Walk around the room (as much as the extension cord allows) showing the students the big electrical spark from the Tesla Coil to the metal tip of the screwdriver. Explain that the Tesla Coil is generating around 20,000 volts of electricity. You can also shock other metal object – BUT NOT ANYTHING ELECTRONIC (it can damage electrical equipment, computers, etc.).

Now ask for a volunteer to get shocked by the Tesla Coil. It is unlikely at this point that you will get any. Turn down the voltage (the knob on the bottom) and shock the back of your hand (don't display any fear – or ham it up!). Turn off the Tesla coil and go to the blackboard to explain why you weren't killed. When dealing with electricity there are two important parameters: voltage (the force with which the electrons are pushed through the wire) and amperage (amps – the # of electrons passing through the wire per unit time). It is the combination of voltage and amperage that kills: V x A = Power (watts). The Tesla Coil generates high voltage (20,000 V), but only very small amps (1×10^{-6} A). Multiplying these together gives a very small power rating (0.2 watts). In contrast, the wall outlet has 110 V and 15 amps, which equals 1650 watts. Which probably won't kill you for a short contact, but will shock the heck out of you. A high voltage power line carries 2,500,000 watts (2.5 MegaWatts) that breaks down as 10,000 V and 250 amps. This would instantly kill you. Explain that static electrical shocks (the kind you get on dry days after rubbing your feet on a carpet and then get shocked when you touch something metal) often generate 10,000 volts, but only a few microamps, so there is very little power present. The Telsa coil generates a similar low power effect.

Now go back and ask for volunteers. You should start getting a few brave souls. Once a few students get shocked, most will want to do it. Don't force anyone to be shocked or let the students tease those that don't want to be shocked. Don't forget the teacher!

Generating Electricity: Discuss how a cordless electric drill or screwdriver takes electricity from a battery pack to power an electric motor to make the drill work. Ask the students to think about the reverse process: turning a drill motor – will that generate electricity?? Get answers from several students. Then have the entire class vote "yes" or "no" about it. The answer is "yes!" – manually turning an electric motor will generate electricity. This is a very nice example of converting one form of energy (kinetic) into another (electricity). Now ask the students if they can imagine a way to power a flashlight without batteries or plugging it into an electrical outlet (no solar cells!). See what they say and discuss their answers with them. Demonstrate the hand-powered flashlight to the class. Ask them how it works. Discuss and explain it to them. These flashlights have a hand-powered generator that converts kinetic energy into electricity. A generator is a motor that basically runs backwards: it takes kinetic energy (motion) and converts it into electricity. It works by your hand providing the power to rotate a magnet (the smaller dark gray metal disk – the bigger disk with the hologram on it is the flywheel to make it spin faster and longer) past two copper coils. I marked the north & south magnetic poles on the magnet in the figure. A magnetic field moving past an electrical conductor (or visa versa) generates an electrical current. This provides the energy to light up the light bulb. Pass the flashlights around and let the students work them. Don't forget to recollect them.



Chemical Energy: Chemicals can also store energy and release it, usually in the form of heat (sometimes as light!). A chemical reaction that releases heat is called an **exothermic** reaction. But chemical reactions can also absorb heat from the environment and get cold. These reactions are called **endothermic** (heat absorbing). You can demonstrate both of these reactions by activating the hot and cold packs and passing them around for the students to feel. The packs have a inner plastic pouch of water and a solid chemical (urea for the cold pack, anhydrous magnesium sulfate for the hot pack). When you squeeze the packs hard enough to break the water pouch, it mixes with the solid chemical and dissolves it. The dissolving of the urea into the water is an **endothermic** process and absorbs heat energy, making the pack get quite cold. The anhydrous (no water containing) $MgSO_4$, on the other hand, loves water and when it dissolves the formation of chemical bonds between the water and Mg^{2+} cations releases heat energy (**exothermic**) and the pack gets quite hot. Warn the students that the hot pack can get quite hot. Finally, you can demonstrate the chemiluminescent light sticks. This is a very unusual chemical reaction where the energy released is directed into producing light and not heat.

Burning Mg in Dry ice experiment: Normally, we put out small flames by spraying them with fire extinguishers, containing carbon dioxide. Most combustion reactions stop after the air source is removed. However, the heat produced by this reaction which begins in the open atmosphere is sufficient to decompose the CO_2. Mg metal consumes the O_2 from the CO_2, while the carbon is reduced to its elemental form, carbon black. This reaction produces a lot of heat and light! ***Always wear your safety goggles.***

> ***SAFTY NOTE:*** The Dry Ice (solid CO_2) is very cold, –78ºC or –108ºF. It can give anyone touching it frostbite relatively quickly. ***DO NOT LET THE STUDENTS TOUCH OR PLAY WITH THE DRY ICE! This demonstration MUST be performed outside! Keep the students at least 10 feet away from the reaction! Have them wear safety glasses!***

Procedure Steps for burning Mg in CO_2:

1) Prior to going outside, explain the chemistry that will happen (you should write this out on the blackboard): $Mg(s) + CO_2(g) \longrightarrow MgO(s) + C(s)$.

2) Take the class outside to an open area (check with the teacher first to make sure this is OK!!). Keep the students about 10 feet away, preferably in a semi-circle around the reaction. Explain what you are doing as you do it. Place the aluminum tray on the ground with several folded newspapers underneath used for insulation. Dump in about two thirds of the dry ice and make a circular mound (use gloves!) with a flat top with a small indentation in the middle top. Dump in the 24 g (approximately 1 mole) of Mg chips into this indentation – make sure there is 1-2" of dry ice below the Mg metal.

3) Use the propane torch to light the center of the Mg chip pile. This should take about 15-30 seconds. The Mg will not burn particularly well at this point, but as long as some of it is burning a little that should be good. Turn off the propane torch and quickly dump a fair bit of dry ice on top of the Mg pile. The Mg should "take off" and start burning brilliantly. **Please ask spectators to stand at least 10 feet away.** A fair bit of smoke (MgO dust) and a few burning Mg "sparks" will come off the reaction. The reaction should stop after about 1 minute. While the reaction is occurring explain the chemistry going on.

4) After the reaction has stopped and cooled off for a minute, peel back the top layer of dry ice/MgO mixture with a pencil or butter knife to see the carbon black produced. A fair bit of the MgO product gets blown out of the reaction as the white smoke. Once the core where the Mg chips used to be cools down, the dry ice and carbon can be dumped in a trash container – preferably a big outside trash can. The dry ice will evaporate away. The carbon is non-toxic.