

Energy: Electricity, Heat, and 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.

Materials:

- 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*)
- roll of aluminum foil (*you provide*)
- insulated container for Dry Ice (*we provide – you must return!*)
- Tesla Coil (*we provide – you must return!*)
- Extension cord (*we provide – you must return!*)
- a big screw driver or wrench (*we provide – you must return!*)
- Generator powered flashlight (*we provide – you must return!*)
- Propane Torch (*we provide – you must return!*)
- 35 safety glasses (*we provide – you must return!*)
- Several H₂/O₂ balloons (*we provide*)
- 4 Chemical Light Sticks (*we provide*)
- 24 g Mg chips (*we provide*)
- Dry Ice (*we provide*)

Safety: 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). 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 a subset of potential energy (stored energy waiting to be released in some fashion). Sound can be considered a subset of Kinetic energy. 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 50,000 V!! Turn on the Tesla Coil (small black button on the side in the middle) and shock the tip of the screwdriver/wrench. 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 (or a good grip on the metal handle of the wrench). 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 50,000 volts of electricity. You can also shock other metal objects – 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. Shock the back of your arm (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: $V \times A = \text{Power (watts)}$. The Tesla Coil generates high voltage (50,000 V) but only a milliamp maximum (1×10^{-3} A). Multiplying these together gives a small power rating of 50 watts. In contrast, a wall outlet typically has 110 V and 20 amps, which equals 2200 watts. This 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 less than a microamp (1×10^{-6} A), so there is very little power present.

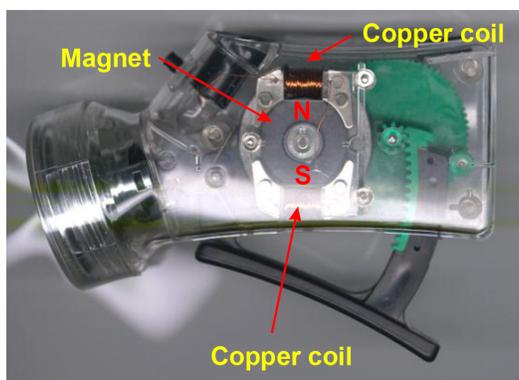
Now go back and ask for volunteers. You should start getting a few brave souls. Once a few students get shocked, most will want to do it. Don't force anyone to be shocked or let the students tease those that don't want to be shocked. Don't forget the teacher! For those students that might be afraid, take the aluminum foil you brought and wrap a layer or two around their arm and make sure it is tight against the skin. You can then shock the Al foil and they won't feel anything. This is because you are spreading out the small amount of power over a large skin surface area, as opposed to a normal "shock" that focuses all the power into one tiny point on your skin. There are quite a few variants of this that you can try out with the students.

You should also have a fluorescent light bulb that you can light up with the Tesla coil. Note that the bulb will only light up to the point where you are gripping the glass (watch the end, you can get a shock from the prongs). This is because the electricity (electrons) from the Tesla coil are being drained out of the bulb through the glass into your body and down to the ground. Demonstrate this effect to the students. Put a metal object on the end prongs of the bulb and hold the bulb with a couple of fingers. If there is a good enough connection to the metal the entire bulb should light up, although it might be dimmer after where you are holding the bulb.

Talk about how energy efficient the fluorescent light bulb is as you are lighting it up with less than 50 watts of power!

Also point out what a good conductor of electricity the body is. Compare how the Tesla coil spark jumps to various materials (wood, paper, metal, plastic, your body). Note that pure water is not a conductor of electricity (most students do not know this). But our bodies contain water with various salts (electrolytes) that makes it a good conductor of electricity. This is why it is so dangerous for you to be out in a lightning storm. Even with rubber soles on our shoes, we are good enough conductors of electricity to look like a metal rod sticking out of the ground. Although wood is an insulator, a live tree has sap and water with electrolytes flowing through the bark and impregnated in the main wood that makes it a better conductor of electricity. This is why lightning will strike live trees. But you are a much better conductor of electricity relative to the tree so if you are under a tree that is hit by lightning, the electricity will travel down the tree and jump to you the better conductor.

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. A great exothermic (exoergic) reaction is the H_2/O_2 exploding balloon. This is a very dramatic (loud) demonstration of a very fast and exothermic reaction. Tape or tie the balloon to the end of a yardstick and have one person (a student from the class) hold the yardstick while another student ignites the balloon with a propane torch or butane “stick” lighter. Both students should be wearing safety glasses. The person igniting the balloon should hold the lighter/torch at

maximum arm's length and approach from the bottom of the balloon. The balloon will detonate and may flash off the hair on the hand if a butane stick lighter is being used. So, if you don't want to lose the hair on your hand, wear a glove and long sleeve shirt (lab coat). It generally will not burn your skin because the explosion and energy are dissipated so quickly.

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 CO₂. Mg metal consumes the O₂ from the CO₂, 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.

Safety Note: The Dry Ice (solid CO₂) is very cold, -78°C or -108°F. 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 (if possible)!

Procedure Steps for burning Mg in CO₂:

1. Prior to going outside, explain the chemistry that will happen (you should write this out on the blackboard):



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 first put a piece or two of dry ice on the pile. It will then almost immediately start burning far more vigorously. Now quickly dump a fair bit of dry ice on top of the Mg pile. The Mg should really "take off" and start burning brilliantly. **Please ask spectators to stand at least 5-10 feet away.** A fair bit of smoke (MgO dust, which is non-toxic but not especially good to breath too much of) and a few burning Mg "sparks" will come off the reaction. The reaction
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.