What is efficiency?

Overview

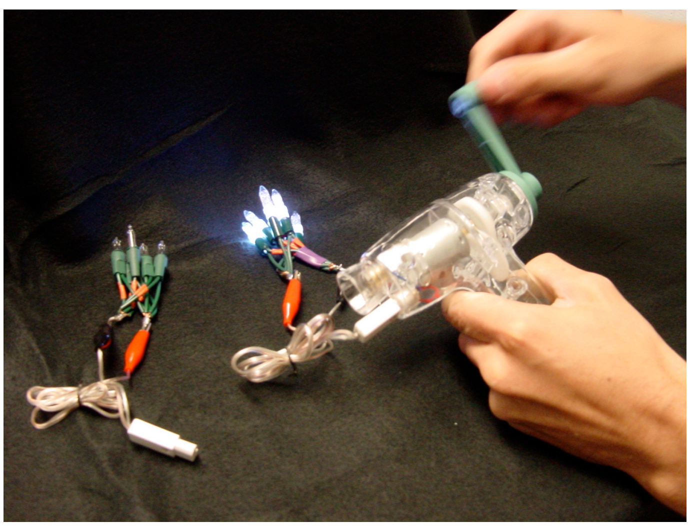
The answer to this question lies in the following Confucian proverb:

"I hear and I forget. I see and I remember. I do and I understand."

In this activity, students will actually feel the difference in energy required to light the two different types of light bulbs. We know that one type is more efficient... But feeling the difference helps students really understand.

Theory

There are two different types of light bulbs. The first type, the kind developed by Thomas Edison, relies on a simple physical principle: When you get something hot, it glows. An incandescent bulb contains a thin wire filament. When electricity passes through this filament, some of the energy in the electrons flowing through the filament is transformed into thermal energy in the filament. The hot filament gives off visible light, but it gives off a good deal more electromagnetic radiation of wavelengths that you can't see. An incandescent bulb that uses 100 watts of electric power only emits 4 watts of visible light. The other 96 watts are emitted at thermal radiation wavelengths. This thermal radiation is absorbed by and increases the thermal energy of objects near the bulb, which is well and good if your aim is to warm something up, but it doesn't make for particularly energy-efficient light production.



Feeling the differences in energy required to light different bulbs.

In the second type of light bulb, electricity excites individual atoms, causing the material they are a part of to glow. This is the technique behind compact fluorescent lights (CFLs) and the newer light-emitting diodes (LEDs). A compact fluorescent bulb can produce 4 W of visible light for an electric energy input of about 25 W — much more efficient than an incandescent bulb! LED bulbs are more efficient yet.

In this experiment, students will light two different types of bulbs — incandescent and LED — using a hand-crank generator to provide the power. Students will see that the bulbs can be equally bright, but achieving a given brightness level with incandescent bulbs takes much more power input than it does with LEDs, so they'll need to work quite a bit harder!

Doing the experiment

There are a few items of preparation you can do that will help this experiment run well. The first involves the bundles of lights mentioned below in the list of necessary materials. For the incandescent bundle, you'll cut 6 bulbs from the strand, attempting to leave about the same amount of wire on either side of each bulb; use the wire strippers to remove a bit of the plastic coating at the end of each resulting tail. Now, take one tail from each bulb and twist them all together; do the same with the other tail from each bulb. Current can flow either way through an incandescent bulb, so it doesn't matter how you orient your bulbs, so long as each has one tail in each twist. You'll need to twist somewhat robustly, as it's important to have electrical contact among the wires of each tail in each twist. For the LED bundle you'll follow much the same procedure, but with a twist. A *diode* (as in 'light-emitting diode') is a device that only allows current to pass one way — LED bulbs have distinct positive and negative ends, and if current is flowing opposite this orientation, the bulbs won't light! Thus, you'll need to make a bundle with all the negative-end wires in one twist and all the positive-end wires in the other. The simplest way to sort which wire is which is to hook up each bulb to the hand-crank generator individually and determine which orientation allows the bulb to light. It's wise to crank with a bit of caution here; all the current you produce will go through one bulb instead of 6, and it's possible to blow out the bulb with too much current.

Necessary materials:

- 1 hand-crank generator (or more if possible; scale other materials accordingly)
- 2 alligator clip leads (1 black, 1 red)
- 1 bundle of 6 clear incandescent holiday lights
- 1 bundle of 6 white LED holiday lights
- infrared goggles (optional)

Please don't do this activity as a demonstration. It's crucial that every student has the experience of lighting both sets of bulbs with the hand-crank generator and observes the brightness of each type of bulb. This activity does work well as a learning station or center your students rotate through.

Speaking of current, something you should know before your students start working with the generators: The current you produce is directly related to the rate at which you turn the generator's handle, and there's an optimal cranking rate for the task at hand. You can work this out ahead of time — what frequency just lights the bulbs to a satisfying degree? Once you've identified this rate, it's valuable to develop a method to help students maintain something akin to it. For example, some teachers play music so that students crank to the beat. However, staying precisely at this optimal turning rate is less critical than turning the handle at about the same frequency when working with the LED as with the incandescent bulbs.

Once you're ready to start the activity with your class, tell your students that they have two jobs to do in this experiment. First they will watch and observe which of the two lights (the incandescent lights or the LED lights) seems brightest to them. Without telling anyone else, they should jot their observations in their notebooks. Second, every student will test each set of lights with the hand-crank generator and decide which set of lights they think is more energy efficient and why. They should record this information in their notebooks.

Before the students begin, demonstrate how to attach the alligator clip leads to the two nails (electrodes) on the hand-crank generator. Explain that you are attaching the black clip lead to the top nail and that this is the negative end. Now attach the red alligator clip lead to the other electrode, the positive end. Show them how to attach the red lead to one end of the incandescent bundle and the black lead to the other end. Explain that they will crank the generator and take notes on the bulb brightness and how it felt to crank it. Explain that when they hook up the LED bulb bundle, one end of the cluster is marked positive and the other negative. They will need to hook these ends up accordingly, as in LEDs, the electricity only flows in one direction.

After all of your students have worked with the bulbs and the hand-crank generator, have them meet in small groups and discuss their findings. Many may be surprised at how easy it is to light the LED bulbs, and how much more effort they must expend to light the incandescents. You may want students to slip on a pair of infrared goggles as they crank the generator and light the bulbs. These goggles block all wavelengths of light except infrared, making it readily apparent which bulbs waste energy at wavelengths that we normally can't see! Have students describe their observations in terms of energy and efficiency, and, in their small groups and with their experimental findings in mind, explain in their own words what 'efficiency' is.

Summing up

This activity offers students a tactile and very striking experience with efficiency. The difference in the amount of energy required to light the LED bulbs versus the incandescents is quite apparent, and connection to a broader discussion of efficiency is natural.

For more information

Colorado State University College of Natural Sciences: http://www.natsci.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu