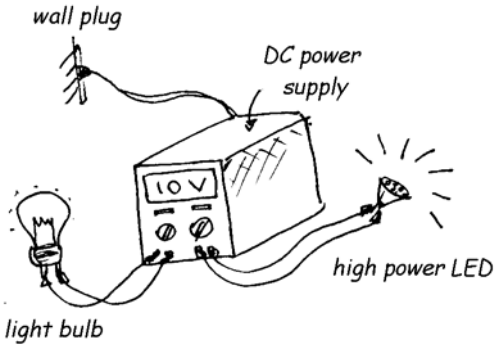
Smart Materials: LEDs

Students are certainly familiar with LEDs but probably don't know the meaning of the acronym. Explaining band theory is probably not a good idea (depending on the level of the class, of course), but many students would welcome a rough idea of what is going on in LED technology.

A good analogy is to relate the *p-n* junction to a fantastic trampoline in a pool. The person using the trampoline to jump into the water must throw their swimsuit away while falling, exit the pool, get a new suit, and start over. In the analogy, the trampoline is the n-type semiconductor, the pool is a *p*-type, the person is an electron, and the suit is the energy that is converted to light. This may sound silly, but it worked great to help students to visualize a *p-n* junction concept. You can then relate the height of the trampoline to the color of the swimsuit, which can be related to wavelength and energy for a more advanced audience.

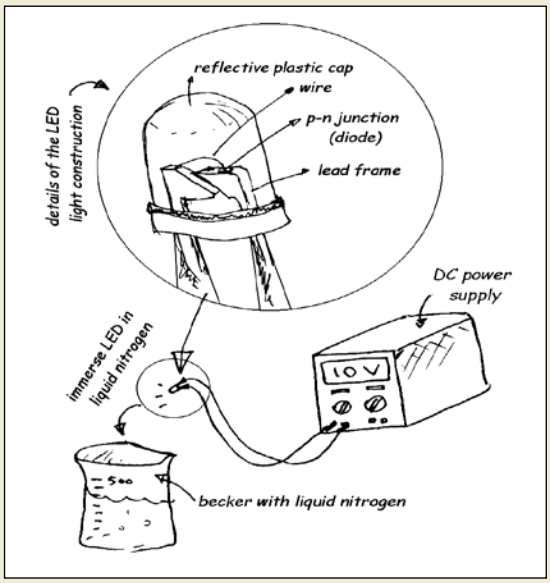
For the experiment, you will need a high power LED lamp. You can find them for less than $30 online. Plug the lamp into a DC power supply and increase the voltage. Use free current by setting it to maximum. The light will only shine at a specific voltage. This is in contrast with the incandescent light, which glows brighter with increasing voltage. In the trampoline analogy, the person can only jump into the water after climbing all the steps to get to the top of the board.



What do you need?

High power LED lamp in colors (blue is preferred), blue light bulb, DC power supply with 30 V/3 A capacity, alligator clips and electrical cords, 500-mL beaker, single LED of different colors, cryogenic liquid nitrogen container, liquid nitrogen.

In another demonstration, take a blue high-power LED lamp and a blue incandescent bulb and plug them both into the DC power supply. Set the voltage to a number where the LED lamp is already glowing and compare the glow from the LED with the incandescent bulb. The LED shines bright using a small voltage, while the incandescent bulb has little glow. This can be related to the energy efficiency of LED technology.



For a third demonstration using LEDs, you can investigate the effect of temperature on the emitted light. A previous experiment demonstrated that temperature affects the mechanical properties of materials. Can it also impact electrical properties? To demonstrate this, we bring liquid nitrogen to the classroom and turn on LEDs of different colors. Do not use the high-power LED lamps for this—the liquid nitrogen can damage their electronic circuits. Instead, use small single LEDs available at very low cost. When ordering, be sure to get color LEDs with a transparent acrylic cap; otherwise you will not see the intended effects. Select a specific color, such as blue, and connect it to a DC power supply. Increase voltage till you see a very dim glow. This means the system has just enough energy to light. Dip the LED into a beaker of liquid nitrogen. Note that the LED no longer glows. This is because the band gap increased such that the applied voltage is no longer enough to cause electrons to flow. Another trick is to use higher voltages to have a color LED fully glowing, then dip the LED into liquid nitrogen. The colors will shift to mostly blue.

What do they learn? Students learn what LEDs are and how they rely on the nature of the materials being used. Creating different colors is just a matter of changing the materials combinations. LEDs are much more energy-efficient than incandescent light bulbs, and temperature does affect their performance.