LEDs Are Diodes

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In this activity, students compare incandescent bulbs and LEDs powered by dc and ac voltage sources. The activity illustrates that LEDs are diodes and shows the relative energies of different wavelengths of light.

Background

LEDs are smaller, more efficient, and longer-lived and have faster switching times than incandescent bulbs. If a voltage is applied to an LED such that electrons in the n-type region and holes in the p-type region move toward the junction (see diagram on Student Side), current can flow, and the electrons and holes can combine and give off energy in the form of light when they cross the junction. If the direction of the voltage is reversed, holes and electrons move away from each other, so very little current can pass and no light is emitted. A diode is a device that passes electric current in one direction only. Familiar single-direction structures include heart valves, one-way streets, and parking-lot entrance spikes.

Integrating the Activity into Your Curriculum

The activity illustrates the structure and properties of matter, the interactions of energy and matter, the relationship of energy and color, and the contributions of chemistry to high-tech materials. Information on where LEDs are used and how chemistry controls the colors they produce can be found in references on the Student Side.

About the Activity

Each student or group needs access to two two-bulb circuits for use with a 6-V battery or four AA batteries in a holder, and one six-bulb circuit with a 12-V ac/ac adapter. The circuits are made from holiday light strands that use 2.4-V incandescent bulbs. In the U.S., these are normally sold in multiples of 50 lights. Avoid opaque-painted bulbs, as they prevent observation of the filament. You will need: several colors of T-1 3/4 LEDs, wire cutter or scissors, wire strippers or knife, pliers, and adhesive tape. Almost any T-1 3/4, 5 mm LED will work. To tell the LED color prior to lighting, select clear (tinted) lenses. To make it obvious that the color comes from the LED and not the lens, select water clear lenses. The box lists sources of electronic materials.

Sources of Materials: **Mouser Electronics**, 1000 N. Main Street, Mansfield, TX 76063 (800/346-6873); LEDs, water clear lenses: 351-5100 (red), 351-5300 (yellow), 351-5500 (green), 604-L53MBC (blue); four-AA battery holder 12BH348, 12BH347, 12BH350. **Digi-Key**, 701 Brooks Avenue South, Thief River Falls, MN 56701 (800/344-4539); LEDs, clear lenses: P305-ND (orange/red), P304-ND (amber), P302-ND (green), P466-ND (blue); four-AA battery holder 2476K-ND; 12-V ac/ac adapter T601-ND. **RadioShack**, www.radioshack.com, (800/THE-SHACK), or from local stores (*); LEDs, water clear lenses: 900-8700 (red), 900-8701 (green), 900-8702 (yellow); LEDs, clear lenses: 276-307* (red), 276-306* (orange), 276-301* (yellow), 276-304* (green), 276-316* (blue); four-AA battery holder 27-409*, 27-383*, 27-391*; 12-V ac/ac Adapter 90-7862.

With the light strand unplugged, cut off the wires at the plug. A single wire goes to all the sockets in series, with one or more wires twisted around it. Unwind the wires and cut the socket wire to make two-bulb and six-bulb segments. Gently strip about 5 mm of plastic insulation from both ends of each segment.

In every six-bulb strand and in half of the two-bulb strands, replace one bulb with an LED. The incandescent bulbs serve as resistors to limit current to the LEDs. Use a variety of LED colors, especially when preparing two-bulb strands. To replace a bulb with an LED, pull the light bulb and plastic base straight out of the socket. Straighten the bulb wires and remove the bulb from the base. Insert the wires of the LED into the base holes. Trim the LED wires so they extend approximately 4 mm. Bend the wires upward with pliers. Push the LED and base into the socket without twisting. Twist or screw the ends of each six-socket strand to the output cord or terminals of a 12-V ac/ac adapter. Cover twisted wires with tape.

Answers to Questions

1. Yes, an incandescent bulb can be heated by its resistance to electrical flow in either direction.
2. Water can only flow in one direction over a waterfall; an LED only lights in one orientation.
3. The incandescent bulb is brightest in series with a red LED, dimmest with a blue LED. The blue LED uses more energy. The energy corresponding to different colors of light increases from red to orange to yellow to green to blue.
4. Current in either direction will heat an incandescent bulb to produce light. An LED connected to an ac power supply passes current only half the time and as a result, blinks on and off. By rapidly moving the light source you can spatially resolve flashing that happens too fast for the eye to resolve without movement.
5. An incandescent bulb produces heat and light. LEDs are typically more efficient in using energy to produce light.

Dashes of light are produced when an LED powered by ac is moved rapidly.

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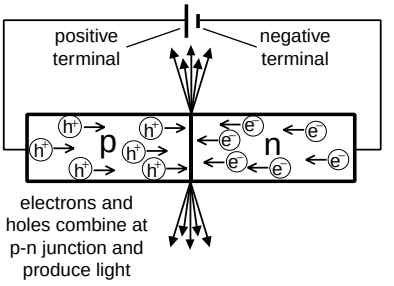
Light emitting diodes (LEDs) have long been used as indicator lights in electronic devices and are now replacing other light sources in applications such as illumination, sports-arena displays, and vehicular and traffic signals. An LED consists of a junction of two different materials: an n-type semiconductor (current carried by negatively charged electrons) and a p-type semiconductor (current carried by missing electrons, or "holes", that behave as positively charged particles).

When electrons and holes meet at the junction, they emit light. The color of light depends on the chemical composition of the semiconductors. Ordinary incandescent bulbs emit light when a thin wire is heated to 3000 °C by its resistance to the flow of electrons. In this activity you will investigate the flow of electricity through LEDs and regular (incandescent) light bulbs.



Try This

You will need: a 2-socket strand with incandescent bulbs, a 2-socket strand with one incandescent bulb and one LED (you can trade with other groups for a strand with a different-color LED), a 6-V battery (or 4 AA batteries in a holder), and a 6-socket strand containing five incandescent bulbs and one LED for use with a 12-V ac/ac adapter. All materials should be obtained from your instructor, since they require advance preparation.

Close-up of an LED assembly. The LED itself is the tiny chip that is indicated by the arrow.

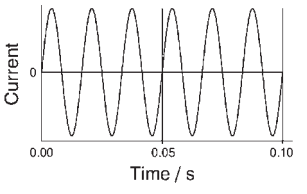
__1. Using a 2-socket strand with incandescent bulbs, touch the two wires to opposite poles of a 6-V battery (or 4 AA batteries in a holder). Do the bulbs light? Now reverse the connections to the battery. Do the bulbs light?

__2. Using a 2-socket strand with one incandescent bulb and one LED of any color, touch the two wires to opposite poles of the battery. Does the LED light? Now reverse the connections to the battery. Does the LED light?

__3. Repeat with 2-socket strands containing other colors of LEDs. How does the brightness of the incandescent bulb change when different-color LEDs (for example, red, orange, yellow, green, or blue) are lit in the circuit? You might want to compare brightness with a neighbor who is using a different-color LED.

__4. A battery supplies direct current (dc) that flows in one direction. In 60-cycle alternating current (ac) the flow of electrons reverses direction 120 times every second. Plug a 12 volt ac/ac adapter attached to a 6-socket strand into a wall outlet. Hold the socket of one of the lit incandescent bulbs and rapidly wave it in a back-and-forth or circular motion. What do you see? Repeat with the same strand but this time waving the LED. Does it appear the same or different? Repeat the waving motion, holding both the LED and one of the incandescent bulbs together for a direct comparison.

Alternating current (ac). Sixty complete cycles are made in one second.



Questions

1. Does your incandescent bulb produce light no matter which way the electrons are flowing through it? Why?
2. Based on your observations in step 2, how is the behavior of an LED similar to that of a waterfall?
3. As long as the voltage supplied by the battery is constant, the sum of the energy available to the incandescent bulb and LED in the 2-socket strand is constant. If an LED requires more energy, then less energy will be available for the incandescent bulb. Based on the brightness of the incandescent bulb in step 3, rank the energy requirements of the different colors of LEDs that are available. Explain your reasoning.
4. Does an incandescent bulb light continuously when connected to an ac power supply? Does your LED light continuously when it is connected to an ac power supply or does it blink rapidly? How can you tell if it is blinking faster than your eye can see?
5. Assuming that the purpose of an incandescent bulb and of an LED is to produce light, can you detect any forms of wasted energy? Which source is more efficient in using energy to produce light?

References and Information from the World Wide Web (accessed Oct 2001)

1. Condren, S. Michael; Lisensky, George C.; Ellis, Arthur B.; Nordell, Karen J.; Kuech, Thomas F.; Stockman, Stephen A. LEDs: New Lamps for Old and a Paradigm for Ongoing Curriculum Modernization; *J. Chem. Educ.* **2001**, *78*, 1033.
2. Lisensky, George C.; Penn, Rona; Geselbracht, Margret J.; Ellis, Arthur B. Periodic Properties in a Family of Common Semiconductors: Experiments with Light Emitting Diodes; *J. Chem. Educ.* **1992**, *69*, 151.
3. LEDs - Light Emitting Diodes; *http://mrsec.wisc.edu/edetc/LED*.