Rainbows in a Box

Author: Ken Robertson
Institute for Chemical Education and Nanoscale Science and Engineering Center
University of Wisconsin-Madison

Purpose: The purpose of this activity is to introduce students to the science of light and color mixing using a variety of modern lighting technologies, including incandescent lights, fluorescent lights, and light emitting diodes, and a simple student-constructed spectroscope.

Learning Objectives:

1. Students should understand that "white light" is actually a mixture of many different colors of light.
2. Students should be able to generally explain how light is produced in incandescent, fluorescent, and LED processes.
3. Students should see the spectra of incandescent, fluorescent, and LED light through simple, personally constructed spectroscopes.

National Science Education Standards:

Physical Science

Transfer of Energy

Science and Technology

Science and Technology in Society

Wisconsin State Standards:

D.8.8 Describe and investigate the properties of light, heat, gravity, radio waves, magnetic fields, electrical fields, and sound waves as they interact with material objects in common situations

G.8.3 Illustrate the impact that science and technology have had, both good and bad, on careers, systems, society, environment, and quality of life

Grade Level: 5-8

Time: 2-3 hours

Materials:
Pizza box (or similar type of cardboard box), holographic diffraction grating (can be obtained from www.starlab.com), duct tape, scotch tape, incandescent flashlight, various colored LED flashlights, fluorescent lights, transparent colored filters, coloring pencils

Background:[1]

Light can be produced in a variety of ways. The three main types of light bulbs currently on the market are incandescent bulbs, fluorescent bulbs, and light emitting diodes. In this portion of the activity, students will use homemade spectroscopes to examine the spectra of various types of light.

Incandescent bulbs produce light by running a current through a metallic filament, producing large amounts of heat. This heating causes the electrons in the filament to become excited; they then decay to a wide range of lower energy levels, producing a continuous spectrum of light which we perceive as "white" light. Colored incandescent bulbs work on the same principles, but use a color filter to emphasize the desired region of the spectrum. Using a spectroscope, one can see this continuous spectrum, which ranges all the way from violet to red.

Fluorescent bulbs produce light through a multi-step process. First, electricity causes mercury vapor atoms to become electronically excited. These excited electrons release photons in the UV portion of the electromagnetic spectrum; however, this light cannot be seen by the human eye. A phosphor coating on the fluorescent tube absorbs the UV light and re-emits it as visible light. However, this re-emitted light only comes in specific wavelengths, not a continuous spectrum. However, these specific wavelengths, when mixed, still appear "white."

LEDs use semiconductors to produce light in discrete bands. LEDs with colors such as red, green, or orange produce a narrow spectrum of colors that combines to produce the color of the LED. The color is determined by the specific combination of compounds in the semiconductor. White LEDs combine several different semiconductor compounds to produce a wide spectrum that is similar to the incandescent spectrum. LEDs have many advantages, including dramatic energy efficiency over other types of bulbs and flexibility in color selection.

Spectroscopes are instruments which break up light into its characteristic spectrum, or mixture of colors. On some level, we can think of a spectroscope as a way of making "rainbows," much as rain droplets break sunlight into its various colors to produce rainbows. In early spectroscopes, a prism was used to separate different wavelengths of light, but now a diffraction grating is used. Since different types of light have different spectra, a spectroscope can be used to identify the spectrum "fingerprint" of the light. In this activity, students will make their own spectroscopes and use them to identify the spectra of different types of light.

Procedure:

Note: Pizza-box spectroscope idea and construction were adapted from PSU ChemTrek activity.[2]

1. Prior to the activity, cut holes in the pizza boxes according to the design in Figure 1.
2. Give students the pizza boxes with pre-cut holes. Students should fold the boxes and tape the edges with duct tape or electrical tape to prevent any extraneous light from entering.
3. Tape a small square of holographic diffraction grating over the viewing hole using scotch tape. Look through the diffraction grating into the box while aiming at an overhead fluorescent lamp – a spectrum should be present to the right of your field of

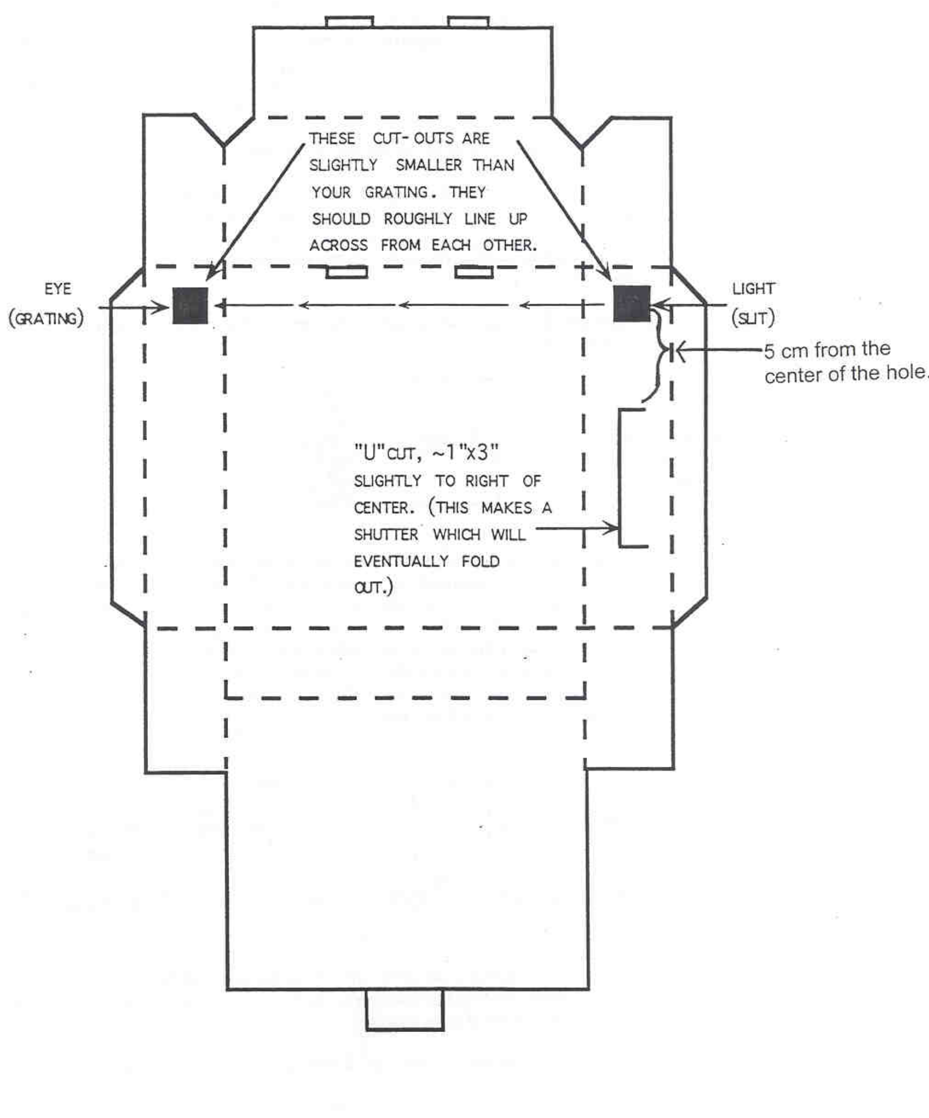
view. If a spectrum is visible below the entry hole, turn the holographic grating 90 degrees in either direction and re-tape.

4. Ask students to describe what they see (rainbow, colors, etc.). Now instruct them to use two pieces of duct tape or electrical tape to turn the hole into a slit. What's the same? What's different?

5. Have students color the observed spectrum of the fluorescent light. The visible spectrum shown on the student handout can be used to guide students where to draw the various colors.

Figure 1

Template for the Cutting of the Spectroscope Box



Note: The U-cut, which serves as the shutter, is optional, and was not used in the initial implementation of this activity.

6. Now allow students draw the spectra of other lights, including LED flashlights and incandescent lights. While students are coloring, ask questions about the similarities and differences of the spectra.
7. Also, allow students to view the incandescent flashlight through various color filters. Students should see that all the colors are still present, but the color of the filter is magnified above the others.
8. After all the lights have been viewed, students should notice that the spectra of different lights look different. Colored LED spectra are in discrete bands (whose location depends on the color), and white LED spectra mix many of these bands together to produce a full spectrum of color, which we see as white light. Incandescent bulbs give off a similarly full spectrum, but fluorescent lights only produce a few discrete wavelengths.
8. After coloring the various spectra, display several lights but keep their identities unknown (LED, incandescent, fluorescent, etc.). Have students look at each light through their spectroscopes and determine their identity (LED, fluorescent, or incandescent) from the spectra.

References:

[1] Condren, S. M. et al. *J. Chem. Ed.* "LEDs: New Lamps for Old and a Paradigm for Ongoing Curriculum Modernization." **2001**, *78*, 1033.

[2] Thompson, S. *PSU Chemtrek: Small-Scale Experiments for General Chemistry*; Keiser, J.T.; Ed.; Hayden McNeil: Plymouth, MI, 2005. pp. 2-15,16,17.

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