Film Can Spectrometers

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Overview:
This activity allows students to understand "spectroscopy" by building and using an inexpensive device for separating light into its component colors, i.e., a "spectrum." Students can build their own gadget and take it home to experiment. They can use the film can spectrometer to identify common light sources via the light's spectral features.

Background:
Measuring an object's "spectrum" is an essential measurement in astronomy but is not an unusual concept in everyday life. A spectrum of a light source is analogous to a recipe of a food item. For example, to make a tasty cake, you must mix specific amounts of various ingredients. If you could measure the cake's spectrum, it would reveal the recipe that was used and would show which ingredients were included and their exact amounts.

Similarly, in astronomy, a spectrum of a light source (planet, star, galaxy) tells you the exact amounts of all the different colors (i.e., "wavelengths") that together make up the light you see by eye. By examining the precise amounts of these component colors, astronomers can learn about an object's composition, temperature, pressure, density, magnetic field, movement, etc. Some of the colors astronomers measure cannot be seen by the human eye: Ultraviolet (UV), X-ray, infrared (IR), radio, etc.

Materials:
Empty plastic film canister (ideally black, not the transparent or translucent variety)
X-acto knife, drill, or drill press
Diffraction grating film
Black electrical tape
Light sources such as:
    incandescent bulbs, "blacklight" bulbs, fluorescent lights, colored advertising lights, etc.

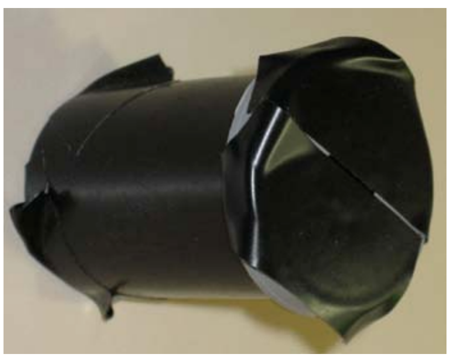
Sources:
1. Film cans (free): A local photography store (Fast Photo, Costco, Walgreens, Target)
2). "Holographic" diffraction film (ScienceFirst.com):
http://www.sciencefirst.com/Holographic-Diffraction-Grating-5.5-inches-wide-by-5.5-feet-long.html
3). Electrical tape: Your local hardware store, Home Depot, etc.

Building the Spectrometer:

1). Using the X-acto knife, cut a crude, opening in the lid of the film canister. Light will enter from this direction into the body of the can. At this time, the opening does not need to be precise. You can also use a portable drill or drill press to make a quarter- to half-inch diameter hole.

2). Cut, or drill, a small (~0.5 cm) hole in the bottom of the canister. Again, precision is not required.

3). Position two pieces of electrical tape across the first opening to make a parallel slit of width ~1 mm. You may find it fun to experiment with the width of this slit during the activity.



4). Cut the diffraction film into small rectangular pieces (~0.25 x 0.75 inch). (These will be affixed to the other side of the film can.) Before cutting, view a light source through the film so you notice in which direction the colors of light are spread out. Cutting the pieces so that the long axis is aligned with that direction will save you and your group some time.

5). Tape a piece of the diffraction grating over the hole in the bottom of the can. Align the long axis of the film perpendicular to the axis of the slit which is located on the other side of the can.

Using the Spectrometer:
Point the slit of the spectrometer towards a bright light source. Look through the hole covered with the grating film, and you should see the light source through the slit. You must maintain this orientation throughout the activity.

To see the spectrum of that source, keep the can pointed at the source and look sideways slightly to the left or right at the inside wall of the can. You should see a spectrum of colors. The colors will be reversed between left and right views.

In order for the spectrometer to work best, the slit should be perpendicular to the direction the grating spreads the light. While examining the spectrum and also holding the can fixed, you can rotate the slit (i.e., the lid of the can) to adjust the orientation of the spectrum.

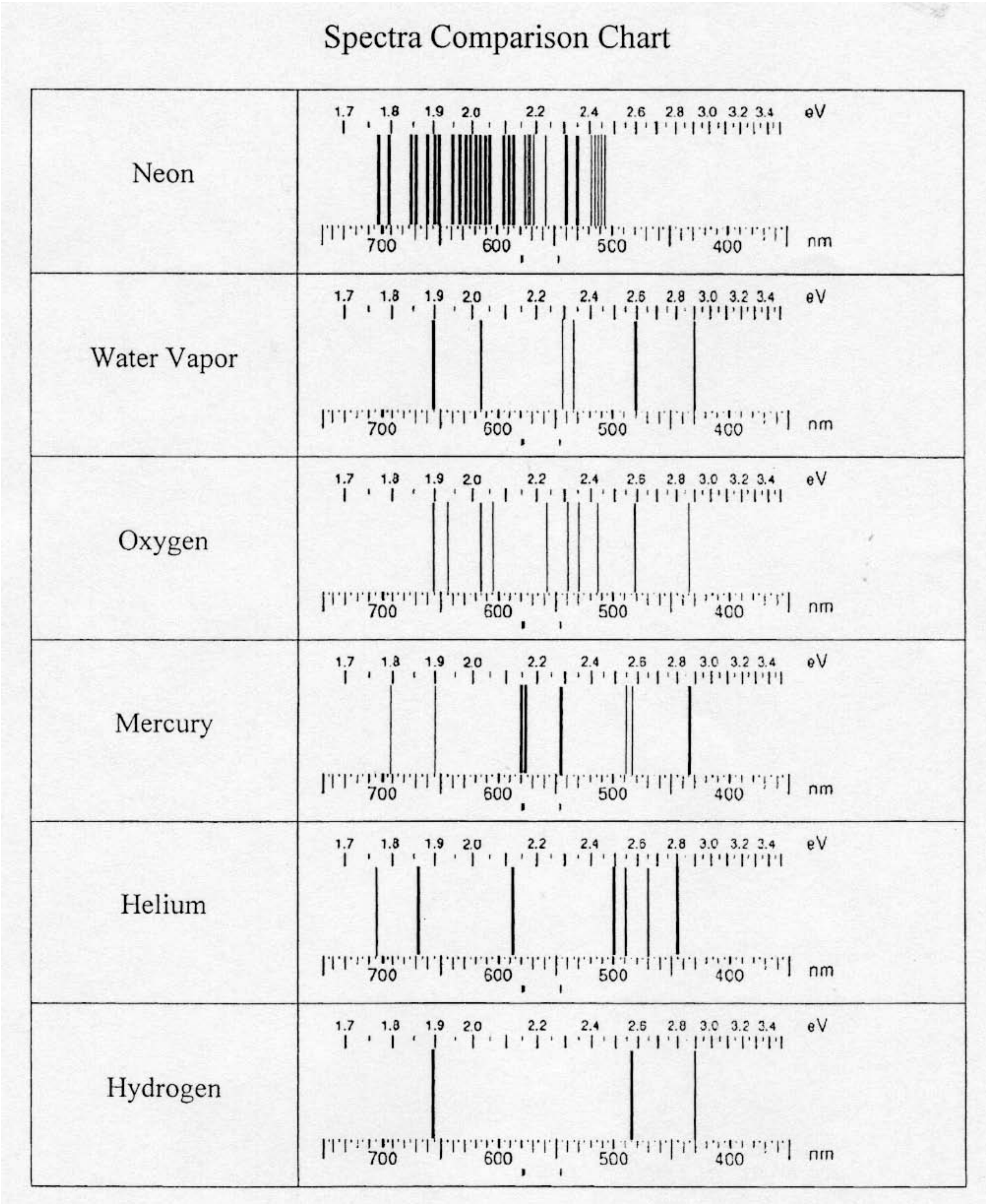
Examining Light Sources:
Use your film can spectrometer to examine, and draw, the spectrum of various light sources around your community. There are two primary types of spectra:

1. A “continuous spectrum” resembles a rainbow and has all the colors present with no gaps between any colors. A household incandescent light exhibits a continuous spectrum because the light is emitted by a metallic filament that glows because electricity flows through it to make it hot.

2. An “emission line” spectrum shows only a few specific colors that appear as colored vertical lines in your spectrometer. Fluorescent lights show such a spectrum, as do various types of “neon or advertising” lights in store windows. Instead of having a filament, those light bulbs have gases inside that also are made to glow by electricity. Each gas shows different colored emission lines.

The following chart shows the emission line spectra of several different gases. Each spectrum is oriented from red (left) to blue (right). A wavelength scale is listed below each spectrum from red (700 nanometers = 700 nm) to blue (400 nm). The upper scale shows the amount of energy carried by different colors of light, showing that bluer colors (shorter wavelengths) carry more energy.

Try using this chart to identify the gases in light bulbs around your home and community. You could organize a Scavenger Hunt!



Besides using advertising lights, you could also purchase various "discharge tubes" from Edmund Scientifics:
http://www.edmundoptics.com/onlinecatalog/displayproduct.cfm?productid=2500