614-0068 (PS-09) Holographic Diffraction Grating

Introduction: light is an odd phenomenon. Although it illuminates the universe, by it self it is invisible. It behaves sometimes as a wave, sometimes as a particle. If it were a wave, phenomena such as refraction (changing direction of light as it passes through a material) are difficult to explain. However, no particle could travel as fast as light does, because it would require infinite energy to do so. Light travels at exactly 299,792,458 m/s. It is hard to imagine a particle traveling this fast. In fact, light travels so quickly it took humanity millennia to realize it traveled at all, instead of moving instantaneously.

In addition to these odd properties, light has the characteristic of being made of many colors, instead of just one. There is no such color as white, as far as light is concerned, but instead an mixture of many colors that appears white. These colors of light can be split using a prism or spectrometer. In addition, the colors produced by objects can indicate a lot about them.

Spectrum Projector for the Classroom: a good place to start when teaching students about the properties of light is to split light from white into many colors. There are two ways this can be done. The first way is to use a prism. Prisms are triangular devices, usually constructed from glass or sometimes other materials. Water will work well. As light enters the prism, it slows. Light will always slow when it passes from one medium to another. In the case of glass, the different wavelengths, or colors of light slow at different rates. This causes them to be reflected inside the prism at unique angles. When the light rays emerge, they no longer travel together, but move at slightly different angles. This causes the colors to break up according to wavelength. Many wavelengths are very similar to each other, so the boundaries cannot be detected with the naked eye. This is why you only see a few shades of red, instead of hundreds. On the other hand, some wavelengths, such as red and blue, are so different that they are easily discernable. Prisms are exceptionally efficient at refracting light, but they're dispersion is generally only a few degrees. Some prisms are made out of advanced materials, such as fused quartz, and have higher dispersion rates. However, these are generally too expensive for the classroom.

Another way of generating a spectrum is with holographic diffraction grating. A diffraction grating uses small ridges, lines, or other mechanisms to create a 'grate' on a clear screen. This blocks some of the light rays hitting the screen, causing them to travel in different directions. This in turn causes the light to disperse into a spectrum. This method creates a very high dispersal rate, but the efficiency is low. To solve this problem, we use a 'phased grating'. This means that the grating sets up varying amounts of phase delay in the light beam. This creates a vivid, linear spectrum, with the efficiency of a prism. Exposing glass plates at the intersection of two laser beams makes these gratings. A photo resistant layer on the glass is susceptible to dissolution by acid when exposed to light. When the exposure is developed, the surface obtains a sinusoidal patter. Electro-deposition creates a nickel copy of this pattern, which in turn is used to emboss a roll of polyester.

To use this grating, you will need a few pieces of cardboard and an overhead projector. Simply placing the diffraction grating on an overhead projector will not do. Instead, overlay two pieces of cardboard on the grating to make a slit. A wider slit will yield brighter colors, but they won't be as defined. A very narrow slit will create a dim spectrum, but the colors will be very monochromatic. It is best to darken the room to create the greatest contrast.

In addition to supporting the diffraction grating, the surface of your overhead projector can also be used for a number of demonstrations. Color filters, liquids, or any transparent substance can be placed on the cardboard slit, showing their own transmission spectrum. Alternatively, students can view the spectrum through these filters. Contrary to popular belief, a colored filter does not change the entire spectrum to its color; it simply makes incompatible potions of a white light spectrum disappear.

There are some interesting phenomena associated with colored filters. For example, an all blue filter will pass some red light. Yellow filters always allow re and orange light through. These properties show that even in monochrome filters, all sorts of wavelengths can pass through. Thus, the old rule of thumb ROY G BIV is inaccurate, because there are many more than seven colors in a spectrum.

Some materials produce what are called absorption lines. When light passes through them, some wavelengths are absorbed so completely that a section disappears from the spectrum. This is because the light in that section is totally absorbed by the material. Chlorophyll for example will absorb the wavelengths of light that plants use for energy. A high-pressure sodium lamp will produce a very broad absorption line. Stars will also produce absorption lines; these are useful for astronomers, but impractical to study in the classroom.

Using small mirrors, it is possible to mix colors from the spectrum. Reflect light of the colors you wish to mix on the same point, and they will blend. Red and green light will produce a yellow indistinguishable from the yellow part of the spectrum. In a fascinating twist, only two colors are needed to show our eyes white light: blue and yellow.

Some materials have the ability to absorb light of a certain wavelength, and reflect it at a longer wavelength. These materials are described as being fluorescent. When ultra-violet light strikes them, they will appear to glow. Ultra-violet light is invisible to humans, so therefore the materials are reflecting different wavelengths. Many fluorescent materials will also glow in the near ultra0violet range; that is, at the edge of the spectrum, where the light is purple. You can try using this portion of the spectrum to test whether or not materials are fluorescent. Some highlighters have fluorescent ink.

In addition, a nice touch is to project the spectrum on a screen or blackboard, and tape a meter stick to it. By carefully adjusting the projector's position, it is possible to make the spectrum cover the range of 40cm to 70cm. This corresponds to the range of visible light, 400nm to 700nm, a wavelength magnification of one billion times.

Some of your students may try to put a piece of diffraction grating over a part of the spectrum, trying to break up the light again. Sadly, the spectrum can only be split once.