Module B. Colour from the Cosmos

Lesson 12: Colour, Light and Optics 1

Illumination

Different sources of energy will emit electromagnetic radiation at different intensities across the electromagnetic spectrum. A simple example of this is a light emitting diode (LED) made to emit only one colour (monochromatic). In the case of a red LED, there would only be light emitted with a wavelength in the ~650 nm range and no light emitted anywhere else along the spectrum. Light sources that are not intended to be monochromatic can have widely different spectral emittance curves depending on the composition of the source of energy we call the "light bulb". These spectral emittance curves describe the intensity of light at a particular wavelength and will often display data only across the visible spectrum (i.e., ~350 nm to ~750 nm).

The figure below compares the spectral emittance curves (sometimes referred to as spectral distribution curves) of three different sources of light, emphasizing the difference in emitted colours across the visible range. Natural daylight (noon sunlight) is well balanced, incandescent lamps (heated tungsten filament) are skewed towards a warm red, and "Cool White" fluorescent lamps have distinct outputs in specific blue and green regions.

This is why something you buy from a fluorescent-lit store (vegetables, clothes, jewellery) might look a little different when viewed outside in natural daylight or in your home under incandescent light. Businesses that depend on visual appearance to make their sales, such as in retail sales of jewellery, are very much aware of this and usually consult lighting experts to optimize conditions in their salesrooms.

Light output from three sources of electromagnetic radiation. Note the difference in relative energy outputs at various wavelengths. Noon sunlight is well balanced across the spectrum, tungsten lamps are skewed towards red, and fluorescent lamps have high peaks in specific localized spectral ranges (~blue/violet and ~green).

The figure below shows a series of spectral emittance profiles for coloured and "white" LEDs. The "Red" LEDs have thier maximum peak located near ~650 nm, while "blue" LEDs have their maximum peak located near ~450 nm. "White" LEDs have a more balanced spectral profile than 'coloured' LEDs. Note how all LED emission profiles are not single lines, but a narrow 'bell curve'. From these plots you can see that if you shined a "Red" LED through a non-absorbing transparent solid, like glass, the transmitted light would still be red. Now, if you have a "blue filter" that lets through only 'blue light' and a Red LED is shined at that filter, there would be very little (red) light transmitted through the blue filter.

Example spectra of light output from different 'coloured' LEDs. The lines are coloured based on the colour the human eye would see.

With respect to gemstones and jewellery, knowledge of how the intensity of light varies according to wavelength is very important when analyzing the resulting colour perceived by our eye. The "colour change" gemstone alexandrite (a variety of the mineral chrysoberyl) is a great example of this. Fine quality specimens will exhibit two distinct colours under specific lighting environments with distinct spectral emittance curves. Other gem varieties that exhibit colour change characteristics include garnet, corundum, and zultanite.

"Colour change effect" exhibited by a single 1.7 carat Oval Cut alexandrite of Indian origin (top) under two different light sources. A blue colour (left) is seen in natural daylight or fluorescent lighting, while a red-pink colour (right) is seen under incandescent lighting. Similarly, the bottom pair of images from a single 17.08 carat stone shows raspberry pink-red (left) under incandescent lighting and blue (right) under fluorescent light. 17 carats for a strongly colour chaging alexandrite is monstrous! This particular stone is the Whitney Alexandrite, from the Hematita Mine in Brazil, and hosted in the Smithsonian Institute.

**OPTIONAL READINGS**

The science of colour, including how our eyes interpret colour and the effects of different colours on humans, is a fascinating and expansive topic. A good start is the Wikipedia site for [Colour](http://en.wikipedia.org/wiki/Color) and associated references or the website [Causes of Color](http://www.webexhibits.org/causesofcolor/index.html), by the Institute for Dynamic Educational Advancement (IDEA) listed at the Introduction to this Lesson. For an excellent book, read *"The Physics and Chemistry of Color: The Fifteen Causes of Color"* by K. Nassau (2001). The UBC Library Physics and Chemistry section has a copy, with call number QC495 .N35 2001.