On Energy and waves

For colors to emerge, there must be light. The prime source of light is obviously the sun. Like a enormous nuclear power plant it produces vast amounts of energy that travels through our universe. It takes about eight minutes the earth.

The energy can be thought of of waves. Each wave looks like the figure below:

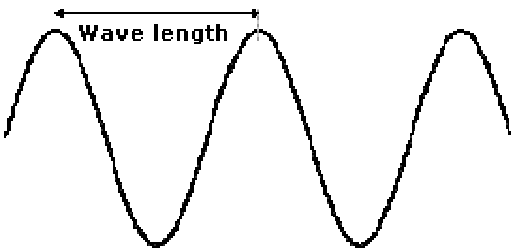

Figure 1: Length of a wave

Like a wave in sea rolling towards the coast, it consists of peaks and bottoms. The distance between two peaks is called the wave length. The energy produced by the sun consists of waves haves all sorts of different wave lengths. The ones with long lengths are known as radio waves, the shortest are known as cosmic rays. There is however a particular range which is very important for us human beings, as only these waves can been seen by our eyes. It is known as the visible spectrum.

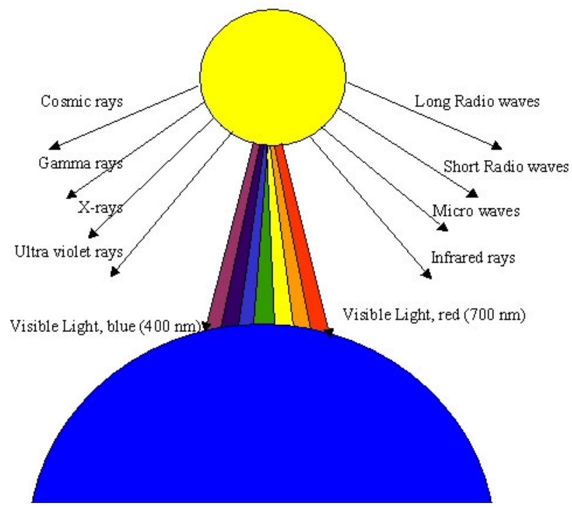

Figure 2: All energy (waves) transmitted from the sun

The visible spectrum is depicted in more detail below:

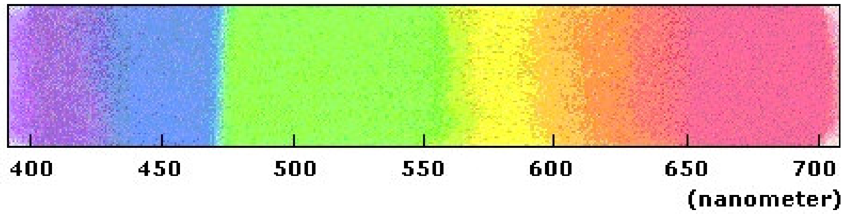

Figure 3: The Visible spectrum

The length of these waves vary from roughly 400 to 700 nanometers (a nanometer is a billionth of a meter). To the left are the waves which are seen as blue light, at the right is red light and all other colors are in between.

On Colors and RGB

So the emits energy, a small part of it can been seen by our eyes and this is light. Although it consists of all colors, packed together it is white. Only when the white light is decomposed by for instance raindrops, its particular components can be seen. Isaac Newton considered the spectrum to be dominated by Red, Green and Blue. Furthermore it appeared that all other colors can be obtained when mixing these three colors. They are therefore known as primary colors. These colors are said to be additive colors and they are used whenever we need direct light to obtain colors. Like using a video beamer or a tv screen.

We only perceive colors when it hits our eyes. Objects that do not emit light are therefore not directly visible. It is only when hit by light we can see them. The light is reflected by the object. Some of the light can however be absorbed by the object. Black object absorb all the light, white none. When absorbed, the light is transformed into warmth. The reflected light determines the color of the object. Object that absorb Blue and Green are therefore Red by definition.

Three colors that are obtained by mixing Red, Green and Blue are especially important:

- Yellow, obtained by mixing Red and Green,
- Magenta when Red and Blue are mixed and finally
- Cyan which is Blue and Green combined.

On CYM and K

A printed image does not emit light by it self. So we must depend on white light hitting the print and waiting for the reflected light to hit our eyes. But this faces us with a problem: for instance yellow light is obtained by mixing green and blue light. However mixing a green pigment with a blue one yields black! That is: the green pigment absorbs the red and blue light. The blue absorbs red and green. So in effect all three primary colors are absorbed, leaving a black color.

In order to overcome this problem, instead of RGB CYM pigments are used: Cyan, Yellow and Magenta. When a Yellow pigment is printed, it absorbs all but the yellow light. Since yellow light is a combination of

Green and Red light, this means that only the Blue light is absorbed by the yellow pigment.

Combining yellow and magenta pigment leads to…? Well, yellow pigment absorbs the Blue light. Magenta absorbs only Green. Together it absorbs both Blue and Green light, having only the Red light reflected. So the printing process is just the other way around. The CYM colors are said to be subtractive.

When mixing different colors of ***Light,*** the result is a color that is combination of those colors. In a way it has more energy, light or color as you will, then the individual light we started with.

When mixing differing colors of ***Pigment***, the result is lesser. Pigments filter the white light. Mixing Cyan, Yellow and Magenta pigments leads to black; all light is absorbed by the pigments. And white? Well, if we use white photo paper no pigment is needed at all.

In practice it is almost impossible to obtain a pure black color. Yellow ink is nearly ideal, but the other two pigments do not absorb all the light they should do, due to impurities in the pigments (ink). Combining the three pigments will result in a brown grayish color. Therefore all printing devices use an extra black pigment, like your ink jet printer.

Using only CYM ink not only deprives us from pure black on the print, it also leads to prints without much contrast. The black ink is therefore used to enhance contrast. This was traditionally done by printing the contrast lines first with black ink, using a so called key plate. The black ink is then referred to as the Key or in short K.

Unfortunately black pigment is also not pure, so usually others pigments of Cyan, Yellow and Magenta are mixed to achieve true blackness. This pure black color is referred to as Rich Black.

On Hue, Saturation and Lightness (HSL)

We discussed two color models so far: RGB and CYMK. There is yet another one which is often used: HSL.

- The ‘H’ stands for Hue, this refers to the name of the color.
- The ‘S’ stands for Saturation, i.e. the strength of the color.
- Finally the ‘L’ stand for Luminance or Lightness, the intensity of light reflected by a color.

The HSL model is a more intuitive model and if mainly used in programs where they let you choose a specific color to paint. In the HSL model a color wheel is used to describe the 'Hue' component:

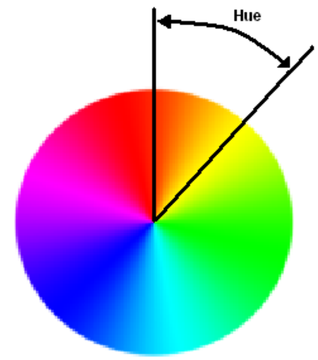

Figure 4: The HSL model

Hue is the amount of degrees to describe a specific color. Red is defined as 0. As you can see from the color wheel, green is defined as 120 degrees, and blue as 240 degrees. The most common colors have the following hue factors:

Color	Hue factor
Red	0
Orange	30
Yellow	60
Green	120
Cyan	180
Blue	240
Magenta	300

Saturation is usually described as a percentage, where 100% is the pure color and 0% is gray. And with lightness: fifty percent lightness is defined as the pure color, 100% yields white and 0% yields black. Perhaps the best way to explain Saturation and Lightness is providing an example, for instance Red:

		Saturation (%)				
Lightness (%)		100	75	50	25	0
	100					
	75					
	50					
	25					
	0					