LIGHT and VISION

LIGHT

There are two general theories to describe the nature of light. One sees light as waves of energy; the other sees light as particles of matter. Both of these viewpoints have been proven to be correct by scientific method, yet the two are incompatible. Things are either waves or particles; energy or matter. They cannot be both! Physicists now call this the wave/particle duality of light. This is one of the major dilemmas of physics today. For the sake of photography it is more convenient to think about light as particles called photons.

REFLECTIVITY

What do you see? You do not see things, at least not directly. Unless you are looking at a light source, what you do see is the light reflected off the surfaces of things. Do you remember when they told you in third grade that you don't really see the moon; you see the sunlight being reflected off of it? Gosh, I really thought I could see the moon. They really like to destroy your beliefs in third grade don't they!

LUMINANCE

is one important term here. It is the measure of how much light is being reflected. This is the amplitude of the light; more commonly called the brightness of an object. The brighter an object appears the greater the number of photons being reflected off its surface. A black sweatshirt looks dark because it is absorbing most of the photons that are hitting it. Conversely, a white shirt is reflecting most of the photons striking it. This is also why dark colored garments will keep you warmer and light colored clothing will keep you cooler.

CHROMINANCE

is the other major aspect of light. Chrominance is the measure of the frequency of light that is being reflected. This is more often called the color of an object. The spread of colors that the human eye can see is called the spectrum of visible light. Remember when they told you in third grade that white light is not really white, but a combination of all the colors? White light sure looked white to me. Your red shirt is reflecting the red end of the spectrum while absorbing most of the other frequencies, whereas your blue shirt is reflecting the blue frequencies and absorbing all the others.

Combining chrominance and luminance gives you light blue versus dark blue and so on. An object can be reflecting a lot of the blue photons or just a few. With black and white films luminance is the major factor determining how things will be recorded. A bright red apple and a bright green pear will look more similar on black and white film than will a bright red apple and a dark red apple.

VISIBLE LIGHT

The spectrum of light that is visible to the human eye is actually only a very small range of the electromagnetic spectrum of energy. This spectrum ranges from gamma rays to x-rays to ultraviolet light above us to infrared light, heat, radar and finally television and radio waves below. Our eyes perceive frequencies from about 400 nanometers to 700 nanometers. A nanometer is one billionth of a meter. The shortest gamma rays (ultrahigh frequencies) are about 10 nanometers while the longest (low frequency) radio waves are 13 kilometers. To make a musical analogy, the visible light spectrum is less than one octave of frequencies while human hearing is about ten octaves - from 20 hertz to 20 thousand hertz. The electromagnetic spectrum is an outrageous 30 octaves. It is worth noting that there are animals that have seeing and hearing ranges that are considerably different than those of human beings (or even musicians).

COLOR THEORY

ADDITIVE COLOR

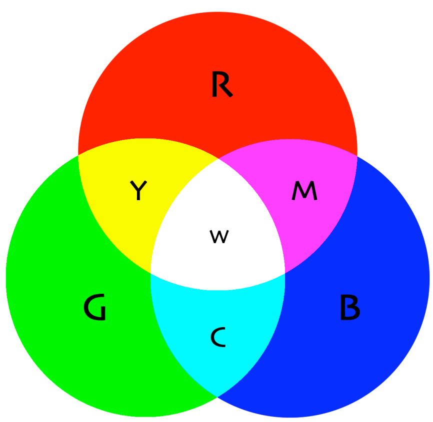
When looking at the world we use Additive Color Theory, where the three primary colors of Red, Green and Blue can be combined in an infinite manner to create all other colors. If three lights are shined on a piece of paper, one red, one green and one blue, where all three lights overlap there will be a white patch. When all three colors are added together, they produce white. Combinations of just two of these lights create the secondary colors in additive theory; Cyan, Magenta and Yellow. Where the green and blue overlap, we see cyan. Where the red and blue overlap, we see magenta. And where red and green overlap, we see yellow.

RGB Screens

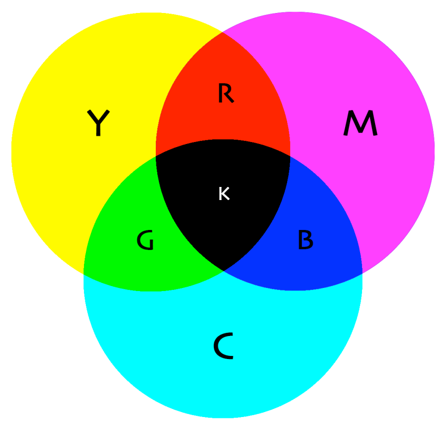
A television screen and computer screen work in exactly the same way. They are both made up of small dots of red, green and blue phosphor or liquid crystal. When there is no electricity going to particular dot it appears black. When all three are turned all the way up their combined light is seen as white light.

Digital Camera Sensors

The sensor of a digital camera is similar. It consists of an array of small diodes that are each sensitive to a particular color - red, green or blue. All the sensor does is capture the color. It is up to the small screen on the back of the camera or a computer screen to produce an image from what is captured. And actually the picture on the screen is an illusion, because all you really see is a collection of red, green and blue dots. The brain is what renders the full-color image. “The picture is what is on the paper, the image is what is in your brain”



additive color



subtractive color

SUBTRACTIVE COLOR

When we are looking at printed photographs we are looking at inks or pigments on paper. The inks absorb some of the light that is hitting them and reflect the rest. The reflective light is best described using Subtractive Color Theory, where the primary colors of Cyan, Magenta and Yellow can be combined in an infinite manner to produce most other colors. Where all three inks overlap we see black. Combinations of just two of these ink colors create the secondary colors in additive theory; Red, Green and Blue. Where the magenta and yellow overlap, we see red. Where the yellow and cyan overlap, we see green. And where cyan and magenta overlap, we see blue.

COLOR CHANNELS

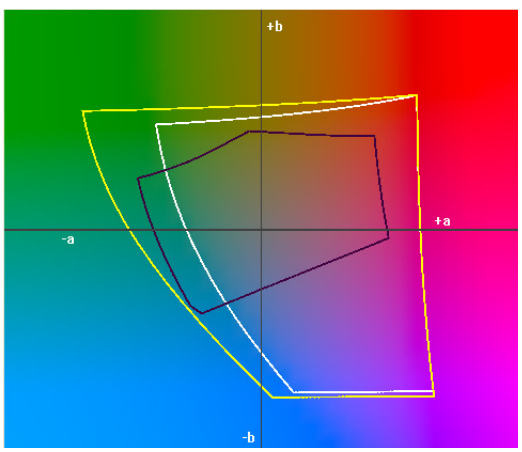
Color film employs three layers of emulsion to make a photograph. One is sensitive to red light, another to green light and the third to blue light. What are produced initially are three black & white negatives, each of which contains the picture information of a specific range of color.

The sensor in a digital camera is made up of an array of three groups of pixels, each group sensitive to only a specific range of color; red, green and blue. Each group of pixels capture the intensity of only one part of the spectrum The data from each group of pixels is stored separately in what are called Color Channels. Since all the data does is indicate intensity (or luminance), each appears as a black & white picture. It is not until these three channels are displayed on top of each other, and each is converted to color that a full-spectrum photograph is seen. These channels can be opened and modified individually in Photoshop. The Channel Mixer uses this same information when converting color pictures to black & white.

COLOR SPACE

Color Space is the term used to describe the range of color that can be used by either a capture device or an output device. Gamut is the term used to measure the width of the color range. The two most common color spaces are sRGB and AdobeRGB(1998). sRGB has a very limited color range designed to meet the lowest common denominator of inexpensive color monitors and it not advisable for professional work.

The Adobe(RGB) 1998 color space has a wider gamut that is much closer to what a professional archival color printer can produce. Photos shot in sRGB will look okay when imported from a camera and will make a reasonable color print but not as good as Adobe RGB. At this time however, Smartphone cameras only work in sRGB. This is in part because they are not really designed for high quality printing.



A comparison between sRGB (white), Adobe RGB (yellow), and CMYK (black)

Notice that photo paper has a wider gamut than sRGB but smaller than Adobe RGB. It is better to work with the larger space and then 'map' these colors to the paper that is being used. Digital SLR cameras have a gamut slightly wider gamut than Adobce RGB.

COLOR TEMPERATURE

The color of light can be measured in degrees using the Kelvin scale, in which 0˚K is absolute zero. The scale runs the same as Centigrade. Daylight is 5500˚K and color-balanced tungsten light is 3200˚K. In reality, daylight changes its temperature throughout the day. But Flash is also set to 5500˚K.

open shade	:	7,000˚ - 8,000˚ K
cloudy or overcast	:	6,000˚ - 7,000˚ K
flash	:	5,500˚ - 6,000˚ K
midday sun	:	5,400˚ K
early morning or late day	:	3,500˚ - 4,000˚ K
studio photoflood bulbs	:	3,200˚ K
household tungsten bulb	:	3,000˚ - 3,500˚ K
sunrise, sunset	:	2,000˚ - 3,000˚ K
candlelight	:	1,000˚ K

WHITE BALANCE

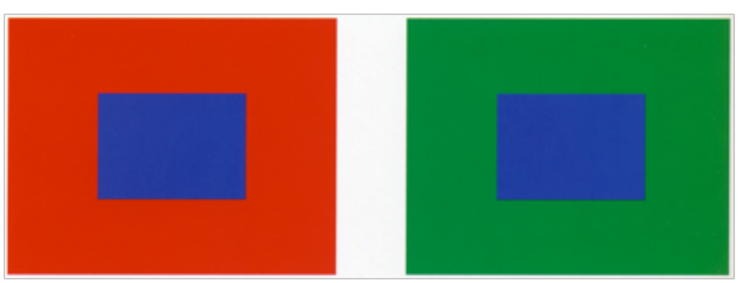
Most people run their Smartphone camera in Auto White Balance. In this case the camera is always trying to guess at what 'white light' really is and varies the color balance for each shot. It is better to adjust the white balance to match the color temperature of the environment in which you are shooting. Bot every camera has this ability. There are apps however, that give you the opportunity to adjust the White balance to better match the original lighting, but you have to remember where you were shooting.

When shooting film, the entire roll is the same emulsion and the color will always be consistent, frame by frame. It is highly advisable to set your camera to a particular white balance so all shots of the same subject will be consistent. It is equivalent to selecting your favorite film and shooting with it because you like the color it renders. Yes, it is possible to reset the white balance with an app, but it is better and easier to get it right in the first place.

Some people actually use White Balance as a creative option. They shoot with the 'wrong' white balance to achieve unusual color effects. Telling the camera that red is white does not make as huge a difference as you might think. Consider the options and experiment.

RELATIVE COLOR PERCEPTION

Adjacent color can change the appearance of color and its intensity. Joseph Albers wrote a breakthrough book on color entitled "Interaction of Color" in the early 1960's. It is now available in paperback for about $10.



Both blue squares are the same color.
They appear different because of the surrounding color.