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COLOR THEORY

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Tone
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Welcome to the world of color and color printing.

Much of this growth certainly can be attributed to the new technologies and products that have made color more accessible, usable and affordable to the general public and business.

But, with this growth has come some misconception of how color works, especially in the areas of:

- color application,
- color matching
- color reproduction.

The Basic

Pixels (Picture Elements)

- bitmap image
- vector graphic

- bitmap images = digital images
  consisting of pixels

pixel = picture element.

smallest individual unit used to construct a digital image

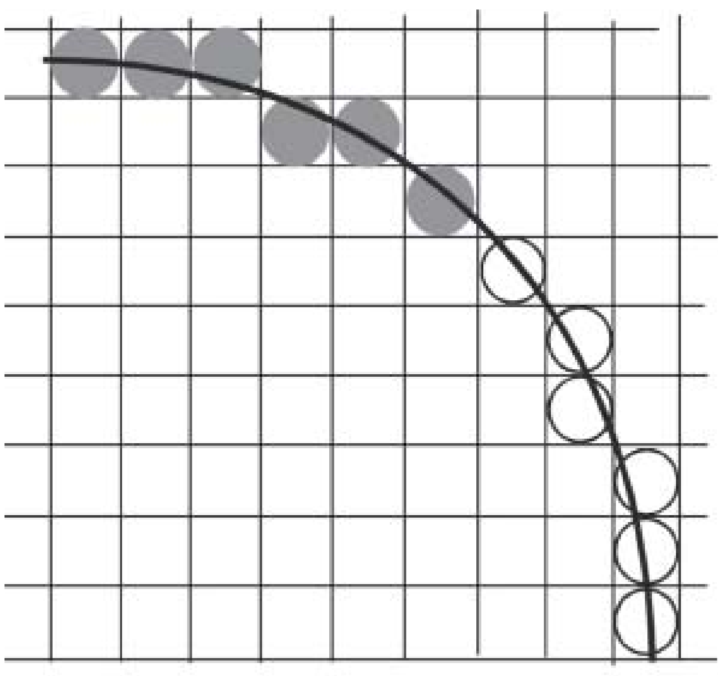
Each pixel is unique in regard to color and/or tone and its location on the x and y axes of the Cartesian system*.

Pixels are placed on a grid called a bitmap.

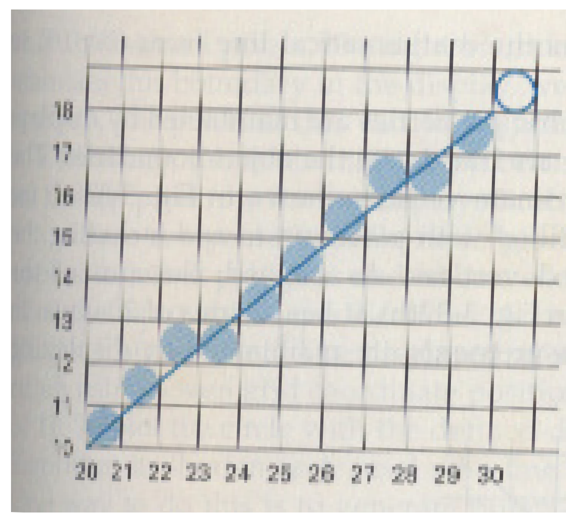
- vector graphic = rely on a language such as PostScript to designate a formula for
  the shape requested
  (line art, circles and squares)

vector graphic

bitmap image



pixel of circle



pixel of line

Binary System

The simplest pixel has two choices: black or white

A pixel with two choices is known as a one-bit image, or two raised to the power of one). Adding more bit information increases the number of color choices. For example a four-bit pixel would have 16 color choices while an eight-bit pixel would have 256 color choices

Color choices increase exponentially as the number of bits per pixel increase.

2^1 = 1 bit = 2 colors	2^6 = 6 bit = 64 colors
2^2 = 2 bit = 4 colors	2^7 = 7 bit = 128 colors
2^3 = 3 bit = 8 colors	2^8 = 8 bit = 256 colors
2^4 = 4 bit = 16 colors	2^{16} = 16 bit = 32,768 colors
2^5 = 5 bit = 32 colors	2^{24} = 24 bit = 16,777,216 colors

Resolution

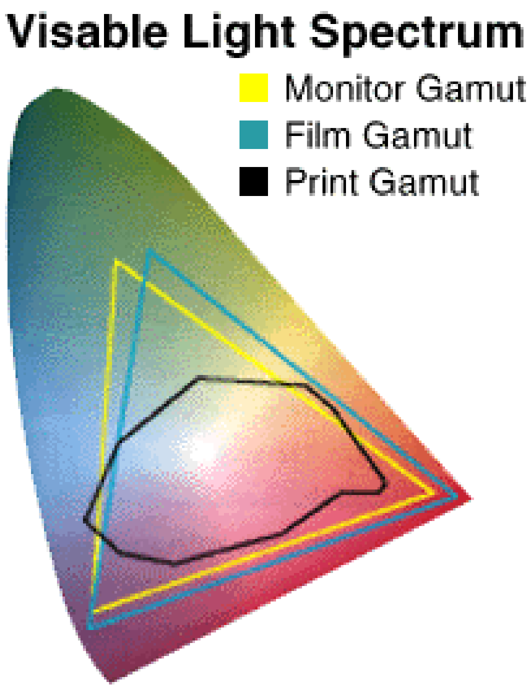
- Resolution is a way of describing images that are composed of pixels.
- An image appears to be continuous based upon its number of pixels and its resolution.
- In order for an image to be continuous, one must not be able to see the individual pixels that were used to create it.

- Resolution of the output device is tied to the number of elements per inch it can address to produce a dot.
- The pixels in the example are shown as squares to represent the address grid.
- Pixels actually produced are usually round or oblong.
- Meeting resolution requirements of the output device is critical to the quality of the image.

For example, the ratio of bitmap images to halftone dots is 2:1.

Color Principles

Electromagnetic energy creates the perception of color.



Color gamuts of color monitor, film and print shown transposed on the 1931 CIE x*y*z* color space.

- For example, the sun provides light which shines on an object such as an apple.
- Some of the reflected light reaches the retina of the human eye which stimulates the brain and the brain creates a perception of the color red.
- The visible spectrum is the range of light that can be seen with the unaided eye.
- Wavelengths above the visible spectrum are infrared
- The wavelengths below the visible spectrum include ultraviolet, x-rays and gamma rays.
- Difference between the
  - visible spectrum we can see with our eyes
  - colors which can be reproduced on a computer screen
  - printed on a color printer.

- Color gamut = the total number of colors that a device can produceut.
- No system can produce all the colors we can see with our eyes.

Tone

- The most dominant wavelengths of the visible spectrum are red, orange, yellow, green, blue, indigo, and violet.
- Tone is
  - the lightness or darkness value of an image
  - and is subjective as it relates to other values in the image.
- Color is what we see and tone is what gives color its depth and form.
- Tone provides shape and definition to color objects.
- Tone would still have depth without color,
- Tonal compression means that the image has fewer tonal steps and is actually loosing values of tone. For example, where dark areas are compressed there are fewer tonal steps resulting in less detail.

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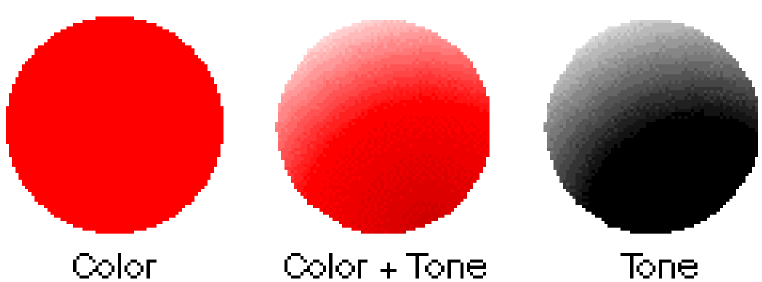
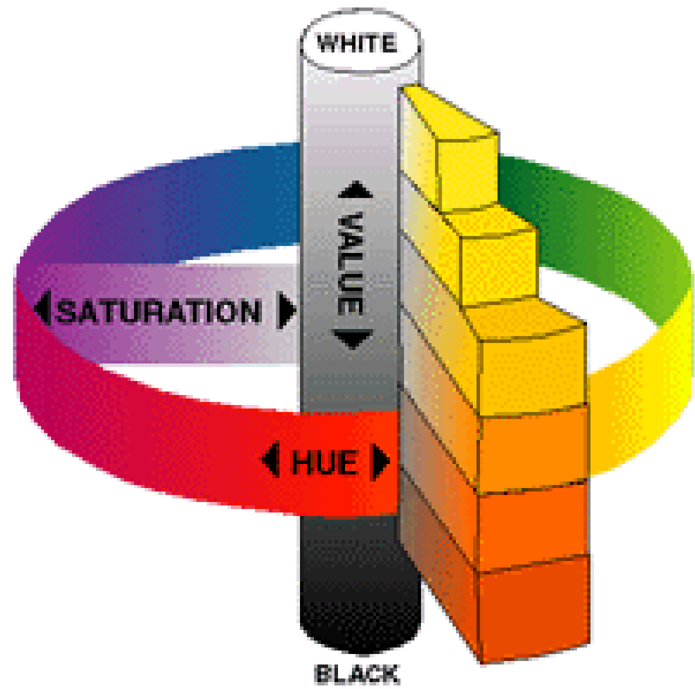


Hue, Saturation and Value



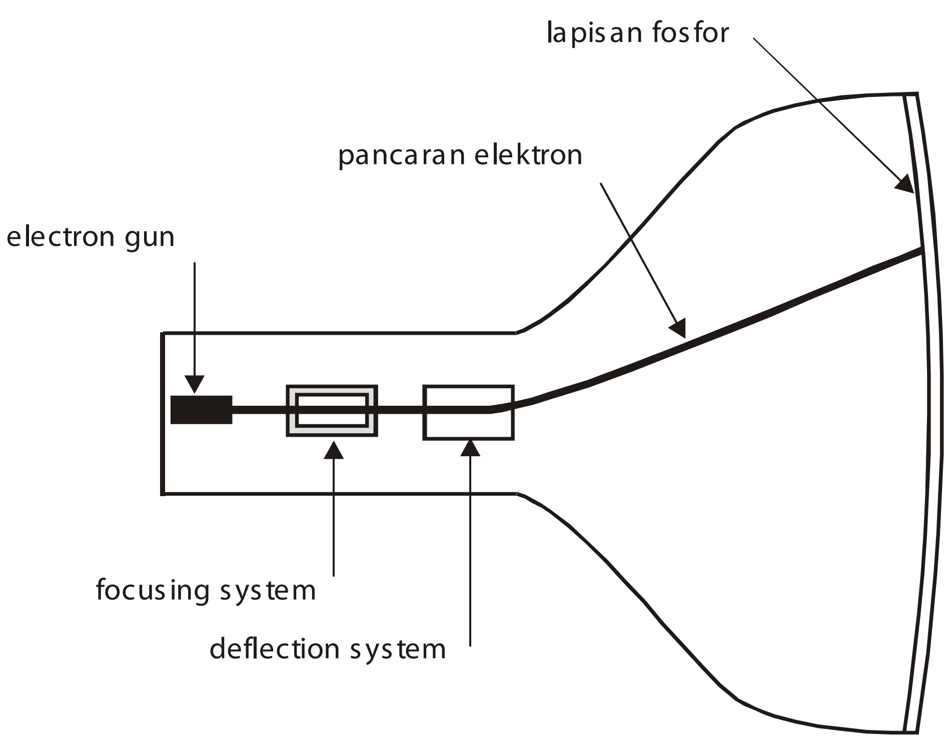
Hue, Saturation and Value Diagram

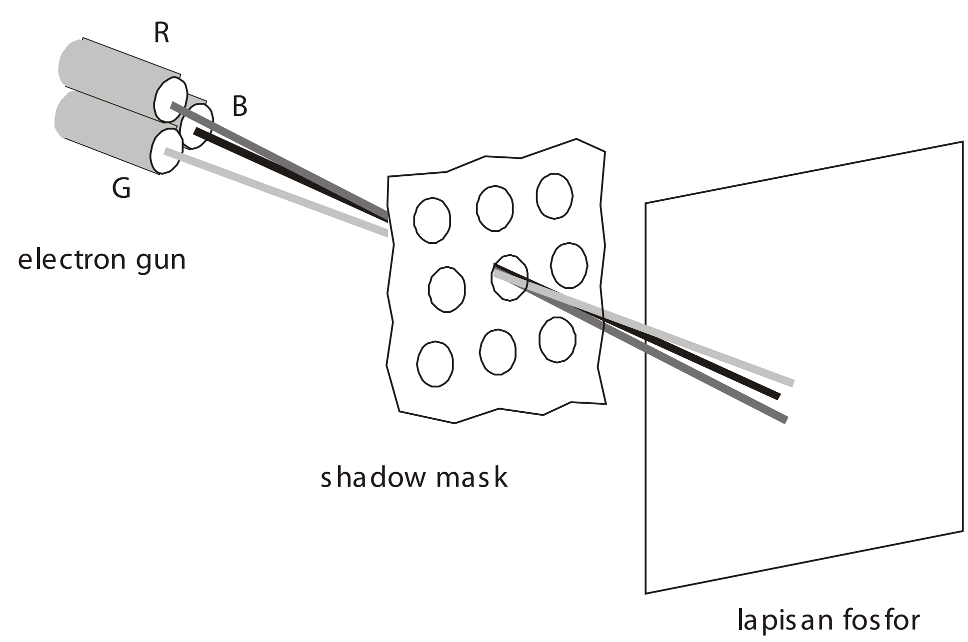
- All colors and tones have an inherent
  - hue,
  - saturation, and
  - value (HSV).
- Hue is the color being described, such as yellow, purple, or green.
- Saturation, also referred to as chroma, is the intensity or purity of the color. (For example, 100% red would be vivid red whereas 10% would be light pink.)
- Value is the relative lightness or darkness of the color.

Additive and Subtractive Color

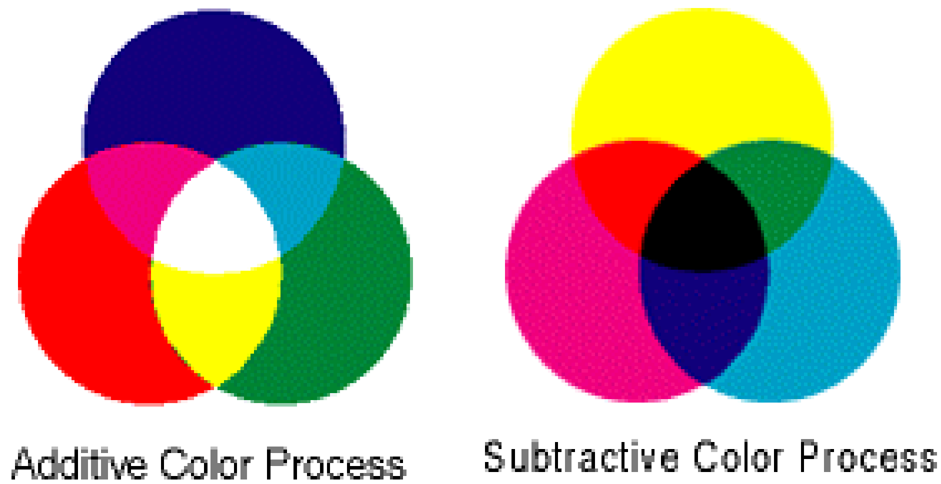
Additive Principle

- The primary colors of additive color reproduction are red, blue, and green.
- When these three primary colors of light are projected on one another in equal parts they produce white light.
- Other colors can be created by varying the intensities of red, blue, and green.
- The absence of RGB colored light results in black.
- Computer monitor is based on additive color.





Subtractive Principle



- Subtractive colors are produced when white light falls on a colored surface and is partially reflected.
- The reflected light reaching the human eye produces the sensation of color.
- Subtractive color is based on the three colors cyan, magenta and yellow.
- Other colors are produced by varying the mixture of these primary colors.
- When these three colors are mixed together at 100% they produce black.
- The absence of CMY pigments would result in white.
- Printing and photography are based on subtractive color reproduction.
- Printing adds a fourth color black which compensates for impurities in the ink.
- The combination of cyan, magenta, and yellow ink results in a muddy brown.
- Black is denoted by the letter K to avoid confusion between blue and black. Hence the C (cyan), M (magenta), Y (yellow), K (black) abbreviation.