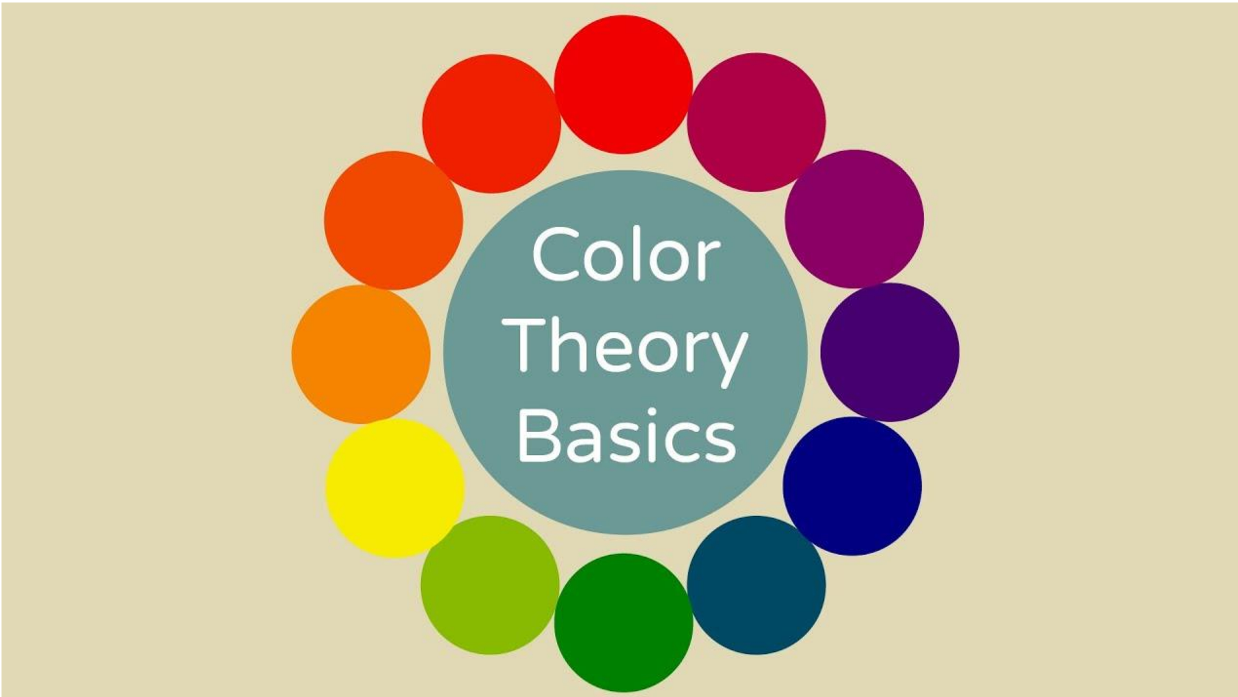
Basic Concepts of Colors



Color is a **visual perception** that results from **light reflection** of objects. The color we see is determined by **the wavelengths of light that are reflected into our eyes.**

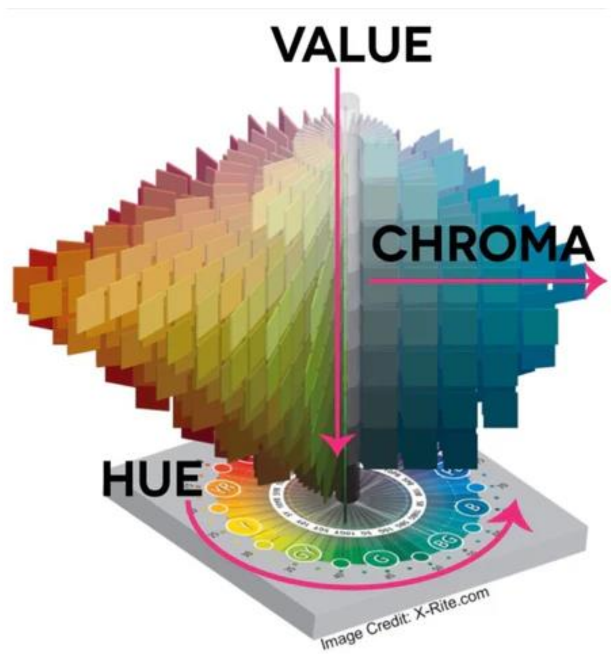
Color Concepts

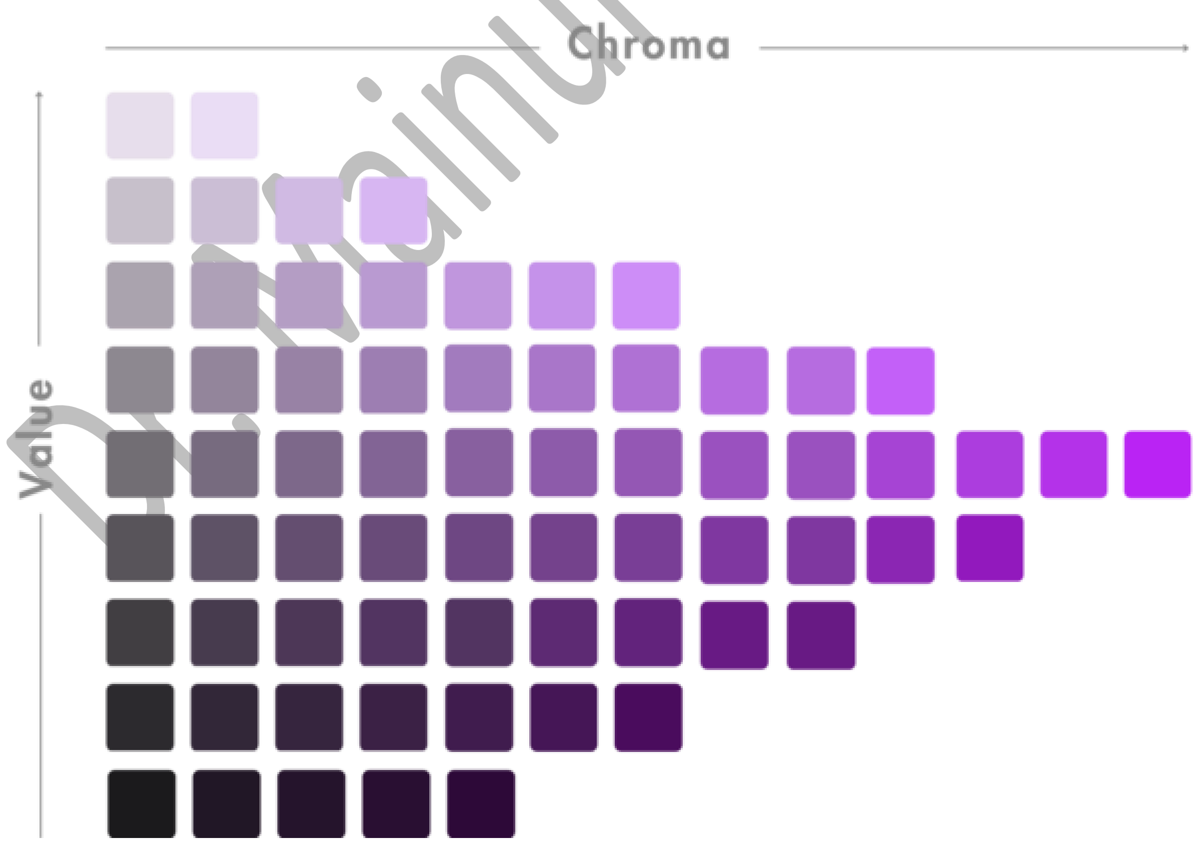
There are **three terms** generally used to describe and specify color. These are hue, value and chroma.

Hue: hue is a term used for color, for example, **pink, mauve, scarlet, beige, tan**, etc are hues. Generally, hue refers to the **origin of the colors** we can see. **Primary and Secondary colors** (Yellow, Orange, Red, Violet, Blue, and Green) are **considered hues**; however, tertiary colors (mixed colors where **neither color is dominant) would also be considered hues**.

Value: value is a term used to describe **lightness, darkness**, **tone or shade** of hues. A color is termed **light in value when it approaches white** and **dark in value when it has a deep color or approaches black.**

Chroma: chroma is the term used to describe the depth of color that is the **dullness, brightness**, **saturation, intensity, vividness or purity** of color. **A bright, intense color is said to have high chroma.**





Color Mixing:

Fundamental laws of color mixing can, therefore, be classified into two types, namely:

1. **Light Theory of Color** or **Additive color mixing** occurs when two or more lights mix together.

   Primary Color: **Red**, **Green**, **Blue**.
   Secondary Color: **R**+**G**= **Yellow**; **R**+**B**= **Magenta**; **B**+**G**= **Cyan**.
   Tertiary Color: **R**+**G**+**B**=**White**.

2. **Pigment Theory of Color** or **Subtractive color mixing** occurs when colorants are mixed together.

   Primary Color: **Red, Yellow, Blue**
   Secondary Color: **R**+**Y**= **Orange**; **R**+**B**= **Pink/Violet**; **B**+**Y**= **Green**.
   Tertiary Color: **R**+**Y**+**B**= **Black**

Color Space/ Color Models

A **color model** is merely a way of **describing color**. These are among the **tristimulus (three-dimensional)** color **models ('spaces')** developed by the **CIE.** A **color space** can be described as a **method for expressing** the color of an object using some kind of **notation**, such as **numbers.**

The **CIE**, is a color space defined by the **International Commission on Illumination** (abbreviated CIE derived from **French** words **Commission Internationale de l'Eclairage**) in **1976**. It has defined color spaces, including **CIE XYZ**, **CIE L*a*b*,** and **CIE L*C*h**, for communicating and expressing object color.

CIE L*a*b* Color Space

When a color is expressed in CIE L*a*b*,

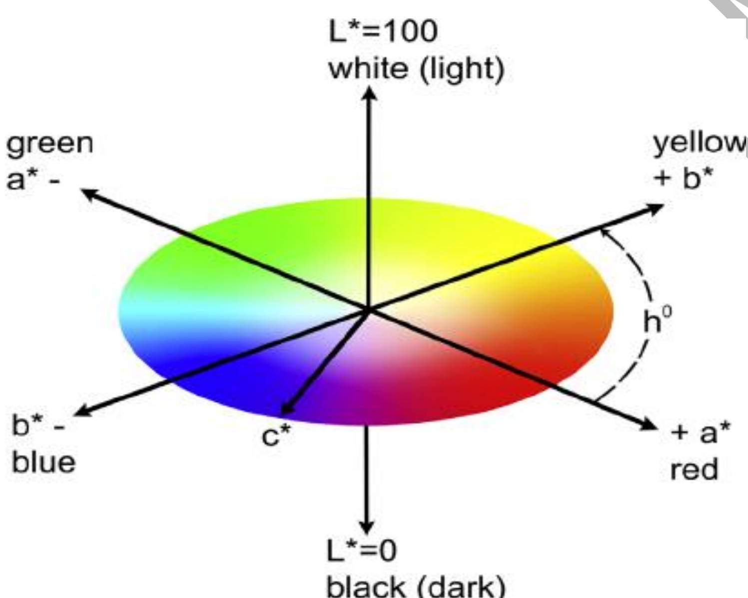
- L* defines lightness (value),

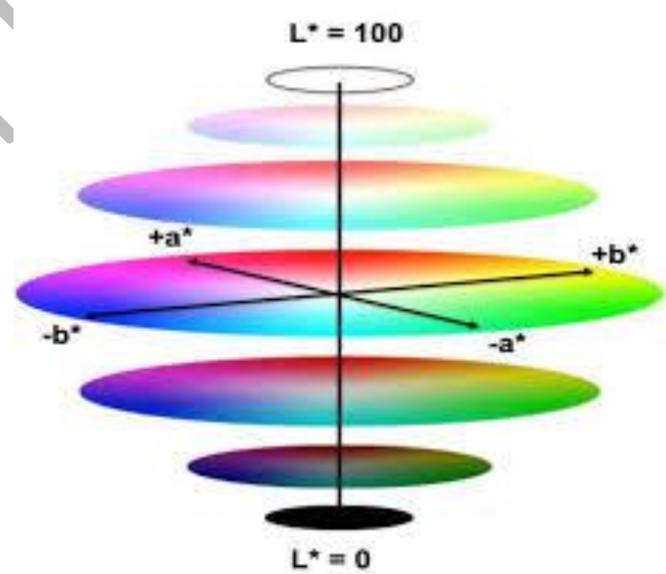
- a* denotes Red/ Green value or attributes and
- b* denotes Yellow / Blue value or attributes.

The **CIELAB space** is **three-dimensional** and covers the entire **gamut (range)** of **human color perception**. It is based on the **Opponent Model** of human vision, where **Red** and **Green** form an **opponent pair** and **Blue** and Yellow form an **opponent pair**.

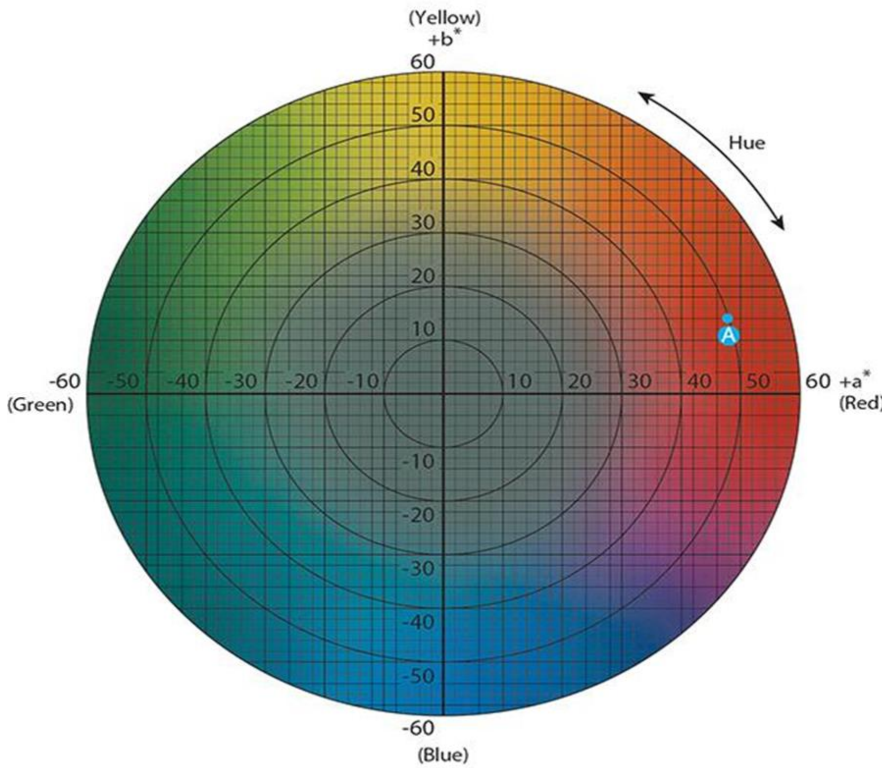
In CIE L*a*b* system-

- **L* axis** is **vertical**, **where L*=0 is black or total absorption and L*=100 is white or total reflection**.
- **a* axis** is **horizontal and perpendicular** to **L axis**. **+a*** value indicates **red hue** and **–a*** value indicates **green hue**.
- **b* axis** is **horizontal and is perpendicular to both L and a axes**. **+b*** value indicates **yellow hue** and **–b*** value indicates **blue hue**.





<u>So, if we say L* =75.5, a*=+52.48, b*= -22.23. This will express a specific color.</u>



- ✓ This is expressed in this color space.
- ✓ **Point A** denote this specific color.

In CIE L*c*h system-

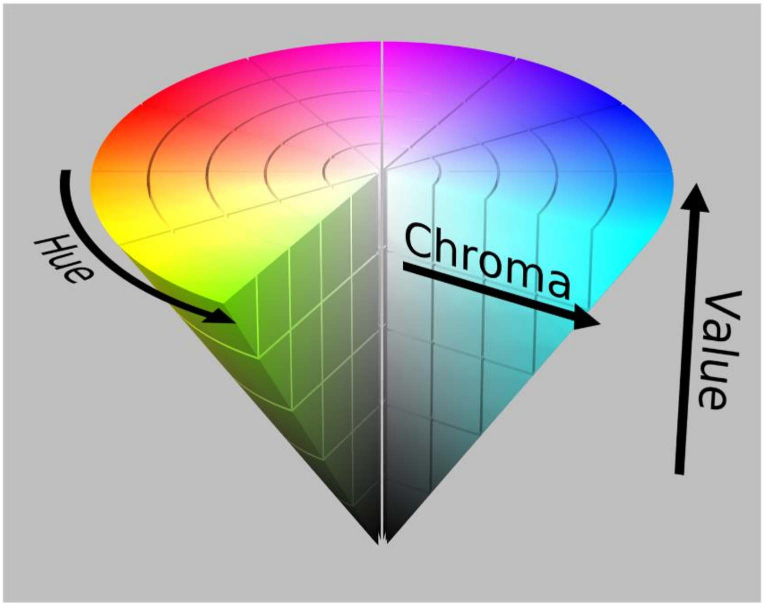
The **L*C*h color space** uses the same diagram as the **L*a*b* color space**, but uses **cylindrical coordinates**.

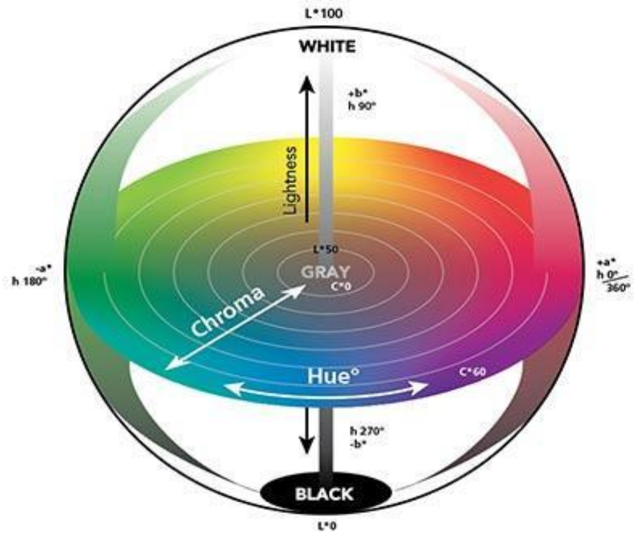
- ✓ The **L*** defines **lightness,** (same as **L* in the L*a*b*** color space)
- ✓ **c*** specifies **Chroma** and
- ✓ **h** denotes **hue angle**.

The values of **c*** and **h** can be expressed in terms of **a*** and **b*** as below:

$$c^* = \sqrt{\left(a^{*2} + b^{*2}\right)} \qquad h^0 = \tan^{-1}\left(\frac{b^*}{a^*}\right)$$

Where, **a*, b*** chromaticity coordinates in the L***a*b* color space.**





Color Differences

Color differences is defined as the **numerical comparison** of a sample to the standard. Even if **two colors** look the same to one-person, **slight differences** may be found when measured with a **color measurement instrument**. If the color of a product does **not meet the standard**, customer satisfaction is compromised and the amount of **rework and costs increase**. Because of this, **identifying color differences** between a **sample and the standard** early in the process is important.

CIE calls their denotes there color difference **ΔE* (also inaccurately called dE*, dE, or "Delta E")** where **delta is a Greek letter** often used to denote difference, and **E stands for Empfindung; German for "sensation".** Use of this term can be traced back to Hermann von Helmholtz and Ewald Hering.

For CIE L*a*b*, color difference formula is-

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}.$$

$$\Delta E = \sqrt{\left\{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right\}}$$

Where, ΔL^*, Δa^*, Δb^* are the differences between L*, a*, and b* values between the specimen color and the target color.

Deltas for **lightness (ΔL^*)**, **chroma (ΔC^*)**, and **hue (ΔH^*)** may be **positive (+)** or **negative (–)** in the **CIE L*c*h color space models.**

- ΔL^* = difference in lightness and darkness **(+ = lighter, – = darker)**
- ΔC^* = difference in chroma **(+ = brighter, – = duller)**
- ΔH^* = difference in hue

$$\Delta E = \sqrt{\left\{(\Delta L^*)^2 + (\Delta c^*)^2 + (\Delta h^0)^2\right\}}$$

Acceptable Range of Color Difference

- ✓ Practically **zero color difference** (**$\Delta E = 0$**) is **impossible**.
- ✓ Even in a **same place of a same colored sample**, if we **test twice** the instrument will show **some color difference**.
- ✓ But there is an **acceptable range** of color difference.
- ✓ If **ΔE** indicates color difference, then-
  - **If $\Delta E \leq 1$**, results **acceptable** and color **matches perfectly**.
  - **If $\Delta E > 1$**, color **does not match** and results **unacceptable**.

Color difference may be in two cases-

- color difference due to **tailing effect** which may **acceptable**
- **Batch to batch** color difference which is a major fault and is **not acceptable**