# Image Processing and Computer Vision



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# Color Model

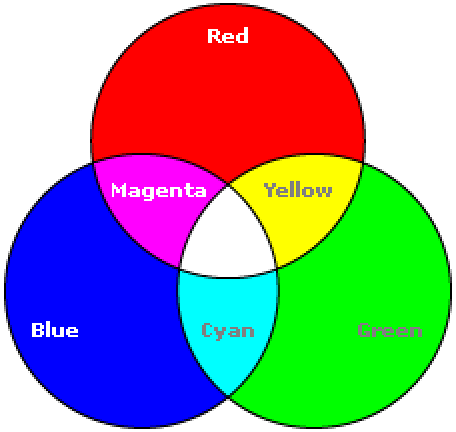
- A color model is an orderly system for **creating a whole range of colors** from a small set of **primary colors**. There are two types of color models, those that are **<u>subtractive</u>** and those that are **<u>additive</u>**.

- ***Additive*** color models **use light** to display color while ***subtractive*** models **use printing inks**. Colors perceived in additive models are the result of **transmitted light**. Colors perceived in subtractive models are the result of **reflected light**.

- There are several established color models used in computer graphics, but the two most common are the **RGB model** (**Red-Green-Blue**) for <u>computer display</u> and the **CMYK model** (**Cyan-Magenta-Yellow-Black**) for <u>printing</u>.

# Additive Color Model

- These type of models use light which is emitted directly from a source to display colors.
- These models mixes different amount of RED, GREEN, and BLUE (primary colors) light to produce rest of the colors.
- Adding these three primary colors results in WHITE image.
- Example: RGB model is used for digital displays such as laptops, TVs, tablets, etc.





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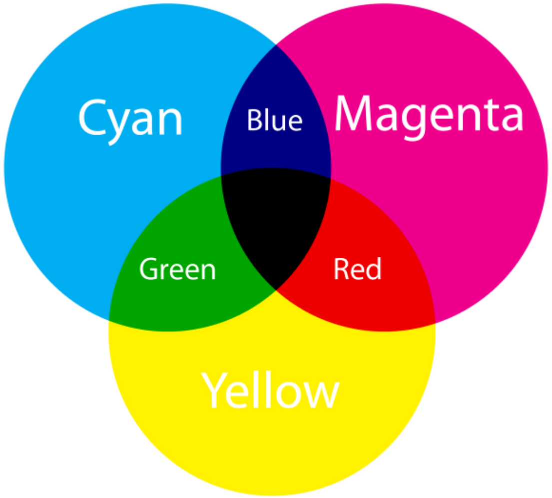
# Subtractive Color Model

- These type of models use printing inks to display colors.
- Subtractive color starts with an object that reflects light and uses colorants to subtract portions of the white light illuminating an object to produce other colors.
- If an object reflects all the white light back to the viewer, it appears white, and if it absorbs all the light then it appears black.
- Example: Graphic designers used the CMYK model for printing purpose.





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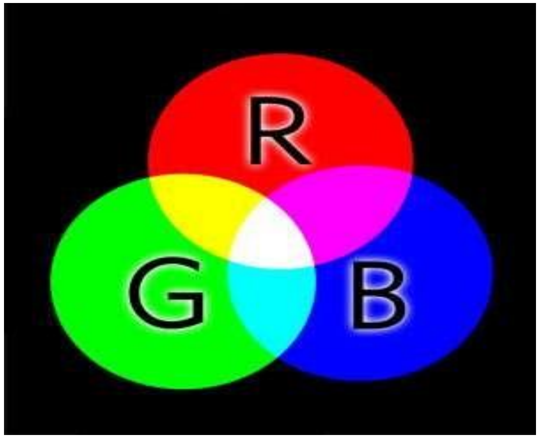
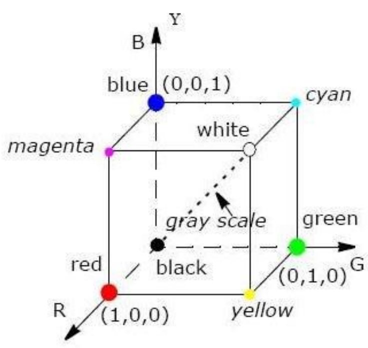
# RGB Color Model

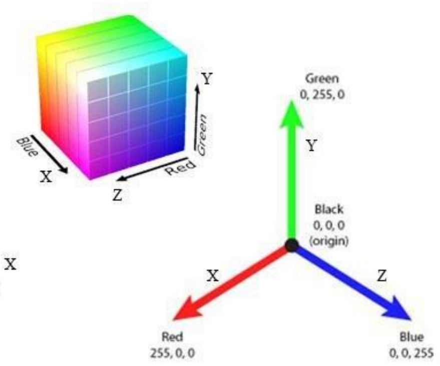
- RGB is an additive color model For computer displays **uses light** to display color , Colors result from **transmitted light**
- **Red** + **Green** + **Blue** = **White**
- Usually, in RGB a pixel is represented using 8 bits for each red, green, and blue. This creates a total of around 16.7 million colors ($2^{24}$). Equal values of these three primary colors represents shade of gray color ranging from black to white.



# RGB Color Model

- If we plot these three primary colors on a 3-dimensional plane in the form of a cube, as shown in Figure ; the RGB values will be at the corners present on the three axes. The origin will be black, and the diagonal opposite to the origin will be black. The rest three corners of the cube will be cyan, magenta, and yellow. Inside the cube, we get a variety of colors represented by the RGB vector (origin at black).
- With the help of the primary colors, we can generate secondary colors (Yellow, Cyan, and Magenta) as follows.
- **Color combination:**
  Green(255) + Red(255) = Yellow
  Green(255) + Blue(255) = Cyan
  Red(255) + Blue(255) = Magenta
  Red(255) + Green(255) + Blue(255) = White



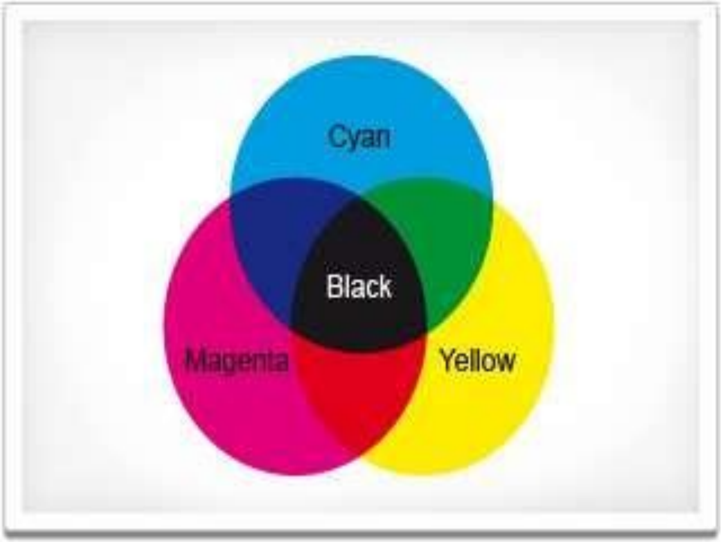



# CMYK Color Model

- CMYK (subtractive color model) is the standard color model used in offset printing for full-color documents. Because such printing uses inks of these four basic colors, it is often called **four-color printing**.

- Where two colors of RGB overlaps, we see a new color formed by mixing of the two additive primaries. These new colors are:

- A greenish blue called **cyan**.
- A blushed red called **magenta**.
- A bright **yellow**.
- The key color **, Black**.





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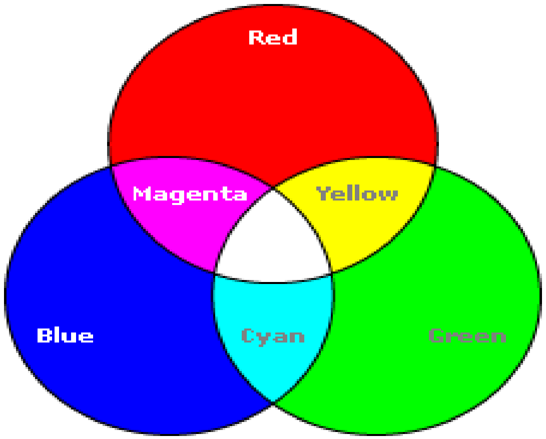
# CMYK Color Model

- We can express this effect pseudo-algebraically. Writing **R**, **G** and **B** for **red, green** and **blue**, **C**, **M** and **Y** for **cyan, magenta** and **yellow,** and **W** for **white**, and using (**+**) to mean additive mixing of light, and (**–**) to mean subtraction of light, we have:




- **C** (cyan) = **G** + **B** = **W** - **R**
- **M** (magenta) = **R** + **B** = **W** - **G**
- **Y** (yellow) = **R** + **G** = **W** – **B**

•In each equation, the colour on the left is called the **complementary** colour of the one at the extreme right; for example, **magenta** is the complementary colour of **green**.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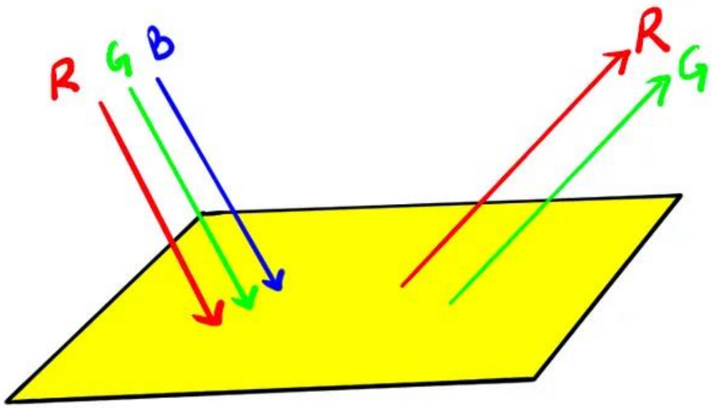
# The Process of Color Subtraction

- The methodology of color subtraction is a valuable way of predicting the ultimate color appearance of an object if the color of the incident light and the pigments are known. The relationship between the RGB and CMY color models is given by:
- **RGB = 1 — CMY** or **CMY = 1 — RGB**
- In other words, red light consumes cyan and vice versa, magenta absorbs green and vice versa, & yellow absorbs blue and vice versa. To understand the process of color subtraction, let's consider a surface of yellow pigment. When a white light (R+G+B) is incident on this yellow surface, the blue lights will get absorbed and we will see only the combination of red and green light as shown in Figure.





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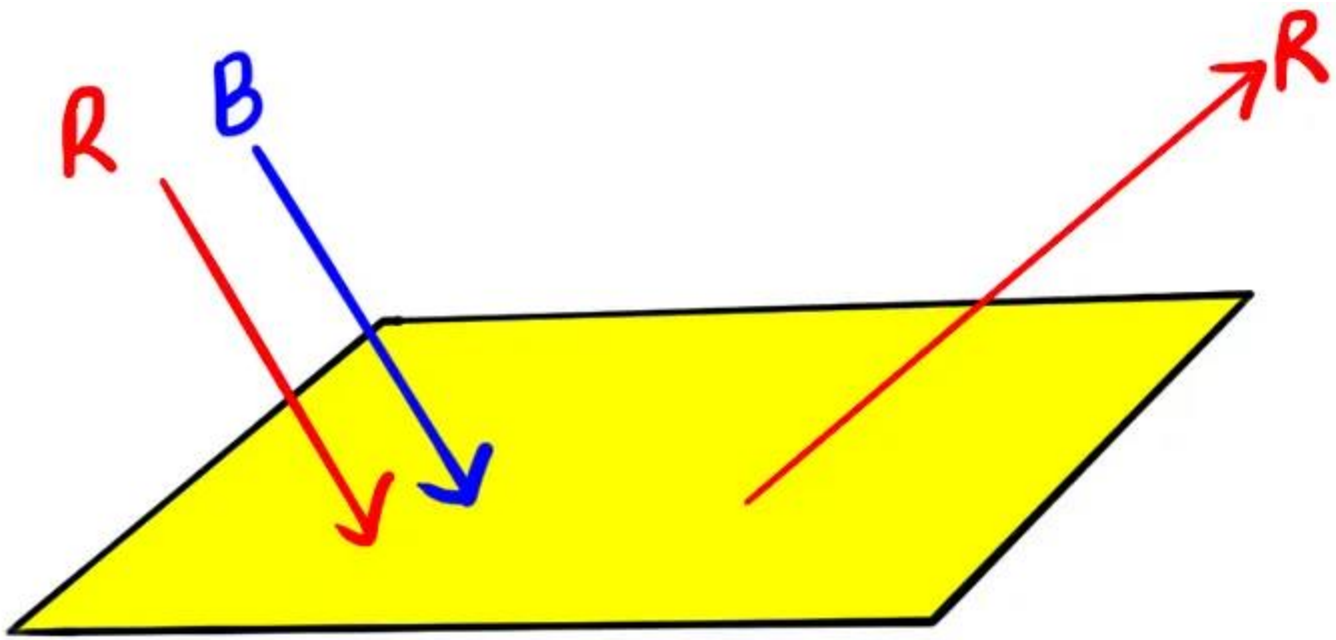
# The Process of Color Subtraction

- Similarly, if we throw a magenta light, a combination of red and blue, on a yellow pigment, the result will be a red light because the yellow pigment absorbs the blue light, as shown in Figure.





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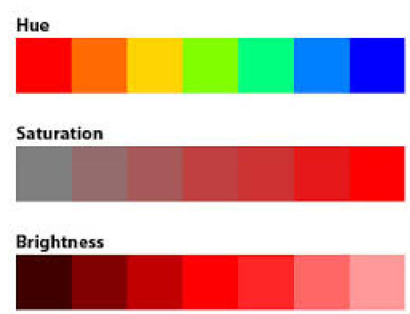
# HSI

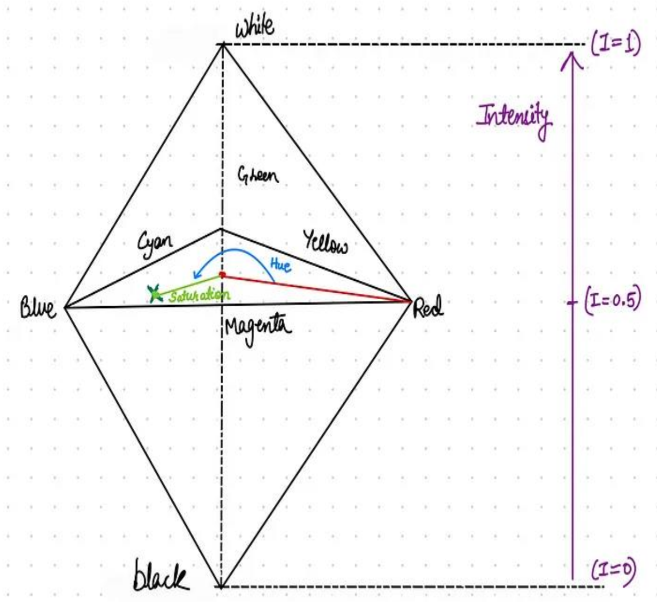
- The RGB and CMY color models are ideally suited for hardware implementations; however, these are not reasonably suited for representing colors in terms that are practical for human interpretation. RGB is not a particularly intuitive way to describe colors. HSI stands for Hue, Saturation, and Intensity. When humans view a color object, its hue, saturation, and brightness are described.

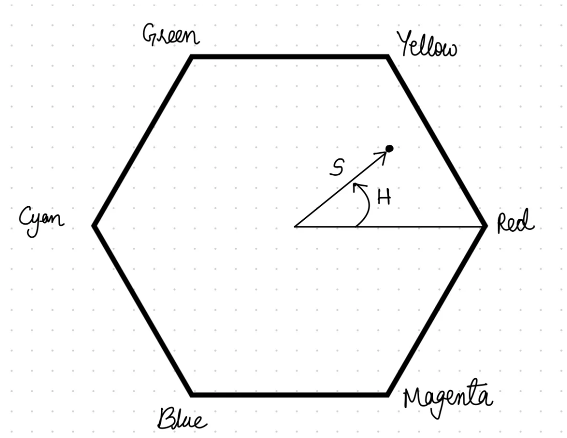
- **Hue:** It is a color attribute that describes a pure color.
- **Saturation:** It measures the extent to which a pure color is diluted by white light.
- **Brightness:** It depends upon color intensity, which is a key factor in describing the color sensation. The intensity is easily measurable, and the results are also easily interpretable.
- **Note:** *RGB is great for color generation, but HSI is great for color description.*



# Calculation of Hue, Saturation, and Intensity

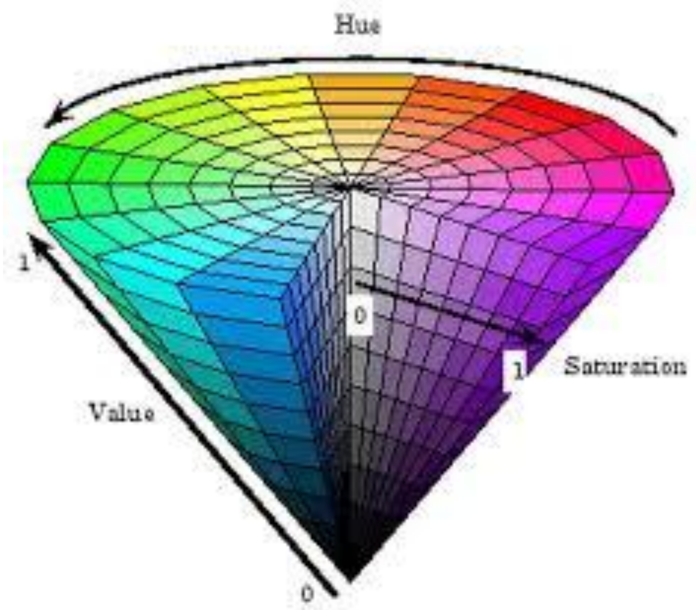
- If we stand the cube on the black vertex and position the white vertex directly above it, we will get something similar to what is shown in Figure. The diagonal (from black to white) or the height of the standing cube represents intensity. At the lowest level, the intensity is zero, whereas at the top the intensity is maximum (=1).
- Therefore the HSI model comprises a vertical intensity axis and the locus of color points that lie on planes perpendicular to that axis.
- Now, suppose we look straight down at the RGB cube as arranged previously; we would see a hexagonal shape with each primary color separated by 120° and secondary colors at 60° from the primaries, as shown in Figure . In this, the hue is the angle from a reference point, usually red, and saturation is the distance from the origin to the point.



# Mathematical Equations to convert RGB to HSI

- **Hue:** Its value ranges from 0° to 360° or can be normalized to 0–1. It can be described as an angle on the above circle, and each degree represents a distinct color.
- **Saturation:** It denotes the amount of color or, more precisely, its percentage or represents the vibrancy of the color. Its value ranges from 0 to 1; 0 means no color, while 1 illustrates the full color. The lower the saturation value, the grayer is present in color, causing it to appear.
- **Intensity:** It has a range of 0–255 or normalized 0–1.



# Mathematical Equations to convert RGB to HSI

$$\text{Hue} = \begin{cases} \theta & ; \text{ if } B \leq G \\ 360^\circ - \theta & ; \text{ if } B > G \end{cases}$$

where, $\theta = \cos^{-1}\left\{ \dfrac{0.5\left[(R-G)+(R-B)\right]}{\left[(R-G)^2 + (R-B)(G-B)\right]^{1/2}} \right\}$

$$\text{Saturation} = 1 - \frac{3}{(R+G+B)} \times \min(R,G,B)$$

$$\text{Intensity} = \frac{R+G+B}{3}$$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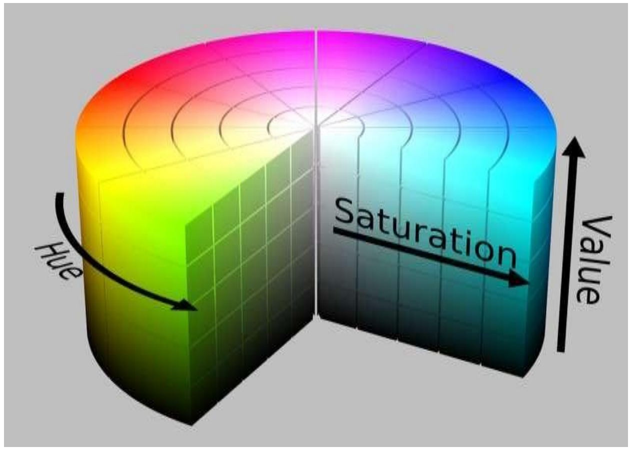
# HSV Color Model

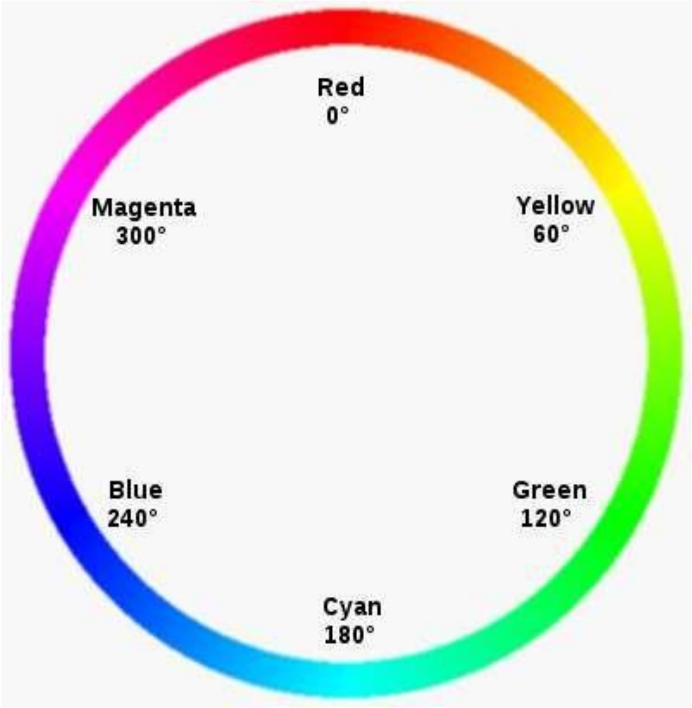
- **Hue, Saturation, Value** or HSV is a color model that describes colors (**hue** or tint) in terms of their shade (**saturation**) and their brightness (**value**). HSV color model is based on polar coordinates; Developed in the 1970s for computer graphics applications, HSV is used today in **color pickers**, in **image editing software**, and less commonly in **image analysis** and **computer vision**.



# HSV Color Model

- Hue (H), the color type (such as red, green). It ranges from 0 to 360 degree, with red at 0 degree, green at 120 degree, blue at 240 degree and so on.

The two representations rearrange the geometry of RGB in an attempt to be more intuitive and perceptually relevant ,based on the color wheel.





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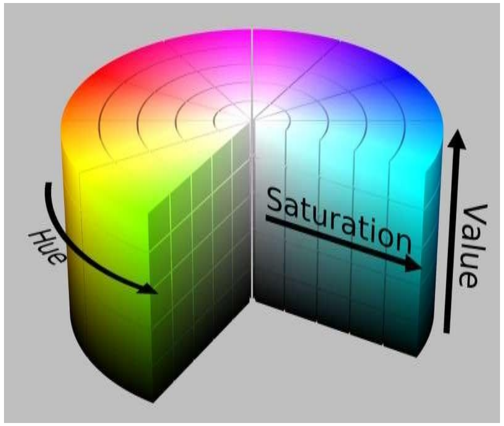
# HSV Color Model

- Saturation (S) of the color ranges from 0 to 100%. Also sometimes, it called the "purity". The lower the saturation of a color, the more "grayness" is present and the more faded the color will appear.

- Value (V), the Brightness (B) of the color ranges from 0 to 100%. It is a nonlinear
- transformation of the RGB color space. Note that HSV and HSB are the same.





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