9. Color Models

As we have seen, the RGB color model can be visualized as a unit cube (a cube with a side of length 1). The RGB model is *additive*; new colors are obtained by summing red, green and blue pigment.

Additive color models work well for luminescent devices, such as monitors, where the value of a color component can be controlled by the intensity of a light source. Additive color models do not work well for *reflective* media, such as a color printer or plotter; nor does the RGB model work well for humans attempting to devise new color schemes.

9.1 The CMY Color Model

The *cyan, magenta and yellow*, or *CMY* color model is useful for producing colors on reflective media. Based on the RGB model it, too, can be visualized as a unit cube, but with cyan, magenta and yellow placed at the unit positions on the X, Y and Z axes.

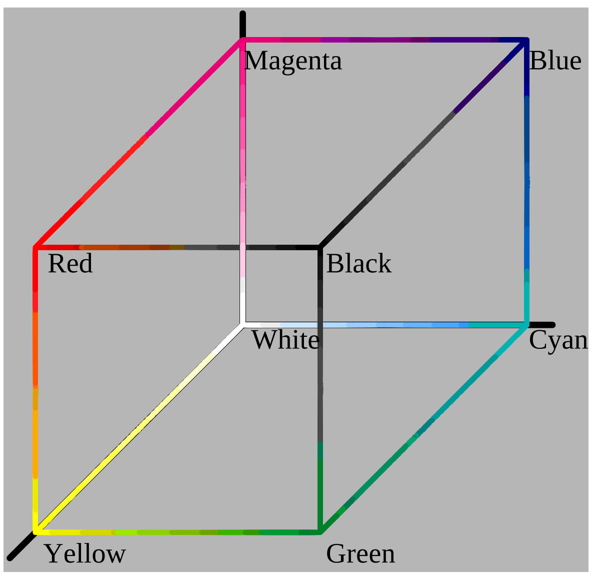

Figure 9-1 The CMY Color Cube

When light is reflected by magenta ink, green hues are completely absorbed, or *subtracted*; therefor we say that the CMY model is a *subtractive* color model. Hard copy color output devices use cyan, magenta and yellow inks to paint a surface with closely spaced dots, or to spray the surface to produce the target color (most such devices use black ink as well).

Within your application you do not typically need to know whether your output device is reflective or luminescent, and choose the appropriate color model to assemble a color. Usually you assemble a color using the RGB color model, then the system or device will translate to the CMY model, if necessary.

Translating between RGB and CMY is straightforward; if color intensities are idealized as floating point values between 0 and 1, then the conversions can be performed as shown in **Figure 9-2**.

RGB to CMY

cyan = 1 - red
magenta = 1 - green
yellow = 1 - blue

CMY to RGB

red = 1 - cyan
green = 1 - magenta
blue = 1 - yellow

Figure 9-2 Converting Between RGB and CMY

9.2 Intuitive Color Models

Humans typically have difficulty selecting a color by mixing various amounts of red, green and blue (or cyan, magenta and yellow). Intuitively, a painter will select a hue, than lighten it by adding white, or darken it by adding black. Adding white to a hue produces a *tint*; adding black desaturates the color to produce a *shade*; adding both black and white produces a *tone*.

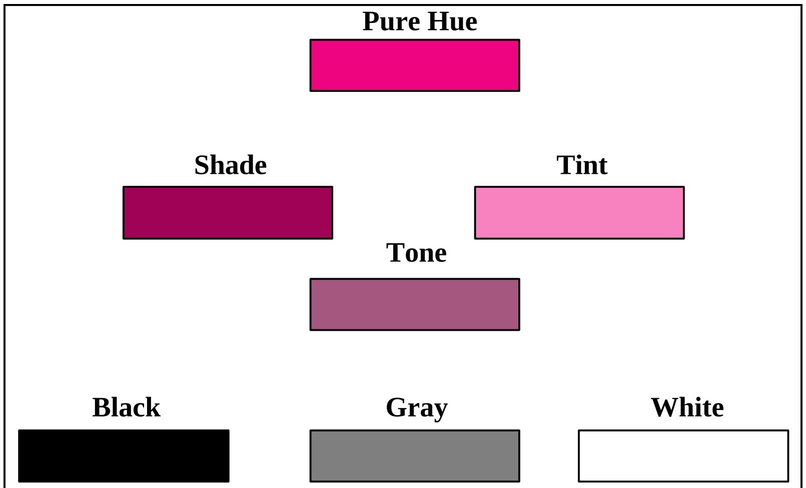

Figure 9-3 Intuitive Color Assembly

Several color models are based on this intuitive concept. The *hue, saturation and value*, or *HSV* model, derived from the RGB model, can be visualized as a hexagonal cone, or *hexcone*.

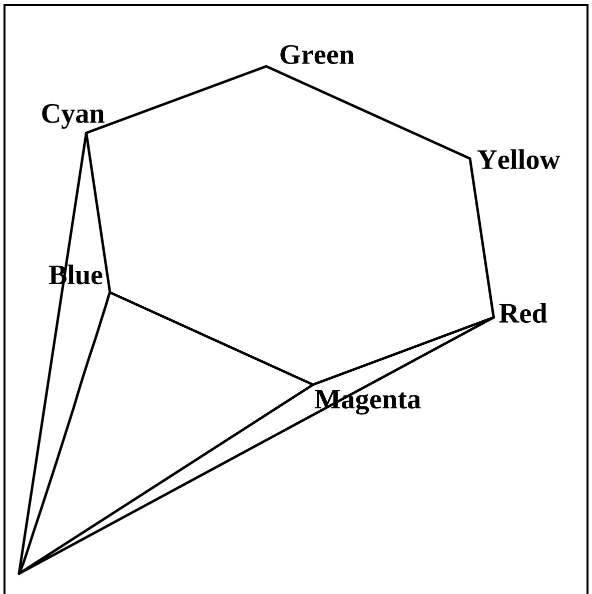

Figure 9-4 The HSV Hexcone

In the HSV model, *hue* is expressed in degrees, between 0 and 360, around the perimeter of the upper surface of the hexcone. *Value*, expressed as a real value between 0 and 1, represents the distance between the origin of the hexcone and the upper surface. *Saturation*, expressed as a real value between 0 and 1, represents the distance between the center of the surface of the hexcone and the hexcone's perimeter.

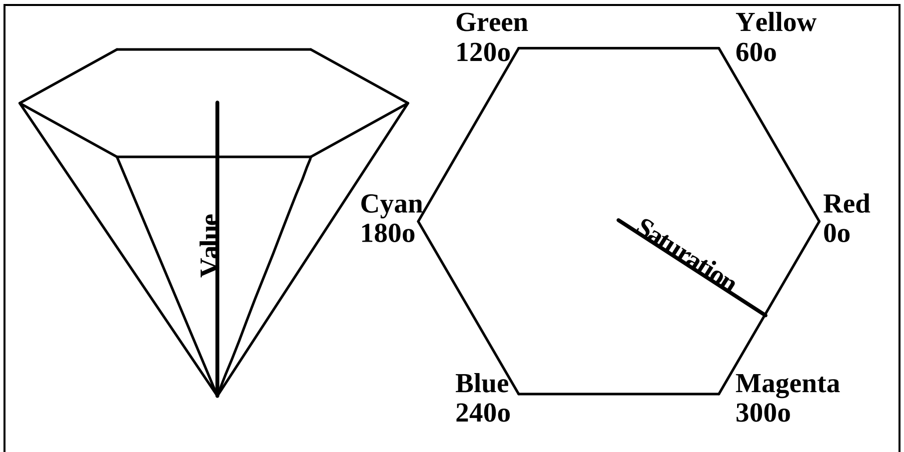

Figure 9-5 Hue, Saturation and Value

Value controls the intensity of the selected hue, and saturation controls hue purity; when value and saturation are both 1, the hue is said to be pure. Decreasing value has the effect of mixing in black, producing a shade; decreasing saturation has the effect of mixing in white, producing a tint. When saturation is 0, hue is undefined and value controls the gray scale: 1 is white, 0 is black, .5 is medium gray, etc.

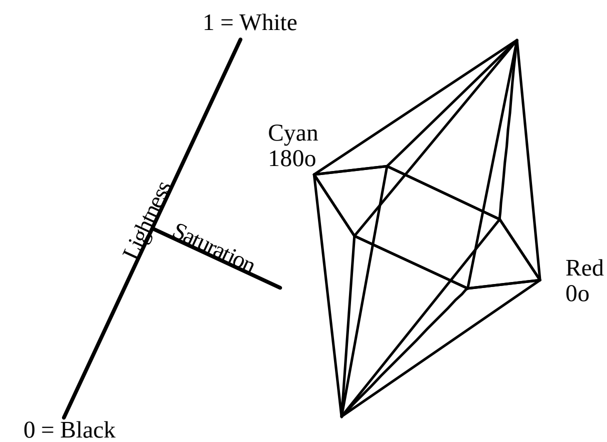

Figure 9-6 The HLS Double Hexcone

The *hue, lightness and saturation,* or *HLS* color model, also based on the RGB model, is similar to the HSV model, but is visualized as a double hexcone. Like the HSV model, hues are represented in degrees around the edge of the surface where the two hexcones meet. Lightness, a value between 0 and 1, is the distance between the origins of the two hexcones; saturation, also a value between 0 and 1, is the distance from the center of the surface to the edge. Pure hues are found when lightness is .5 and saturation is 1. Decreasing lightness to 0 darkens the selected hue to black; increasing it to 1 lightens the color to white. Decreasing saturation decreases the purity of the selected hue. When saturation is 0, hue is undefined and lightness controls the gray scale.

Since the HLS and HSV color models are transformations of the RGB color model, values in one model can be translated to values in any of the other models. Consult your text book for details.

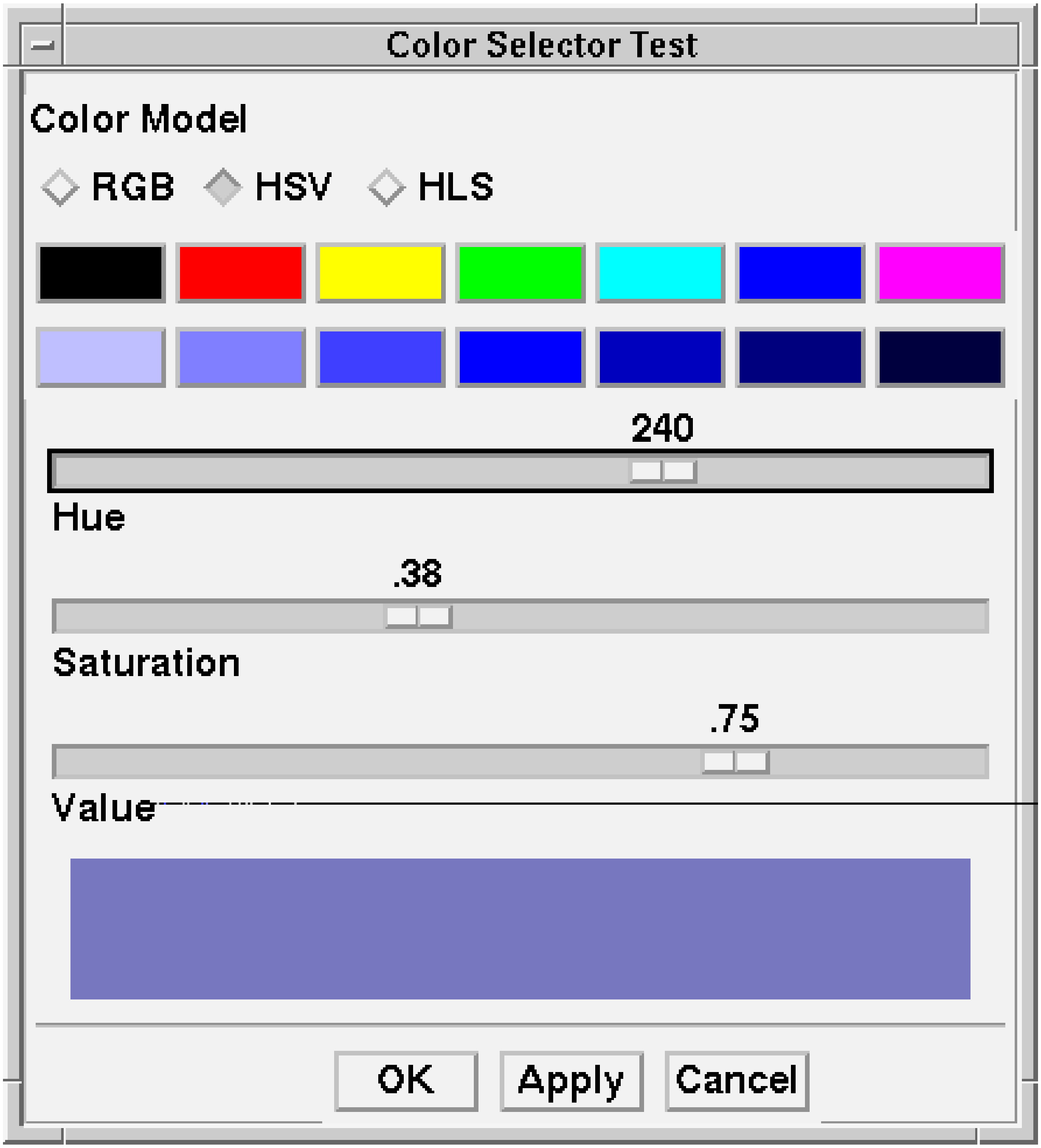

Figure 9-7 A Color Selector