Review Questions

1. *Discuss the properties of light.*
2. *Define chromaticity, complementary colour of amount and primary colours.*
3. *Explain CIE chromaticity diagram.*
4. *Explain the usefulness of CIE chromaticity diagram with examples.*

11.5 Intuitive Colour Concepts

- It is possible to make **pure colour** lighter by adding a white pigment and darker by adding black pigments to it. Thus, different tones/shades of the colour are produced by adding both black and white pigments.
- Describing a colour as a set of three numbers that give the relative proportions of the primary colours, it is generally much easier to make a colour lighter by adding white and make a colour darker by adding black. Therefore, graphics packages generally provide two or more colour models colour palettes to a user often employ two or more colour models.
- Therefore, graphics packages providing colour palettes generally use two or more colour models colour. One colour model provides an intuitive colour interface for the user, and others describe the colour components for the output devices.

Review Question

1. *Explain intuitive colour concept.*

2

11.6 RGB Colour Model

AU : Dec.-11

- The red, green and blue (RGB) colour model used in colour CRT monitors and colour raster graphics employ a cartesian co-ordinate system.
- In this model, the individual contribution of red, green and blue are added together to get the resultant colour.
- We can represent this colour model with the unit cube defined on R, G and B axes, as shown in the Fig. 11.6.1.

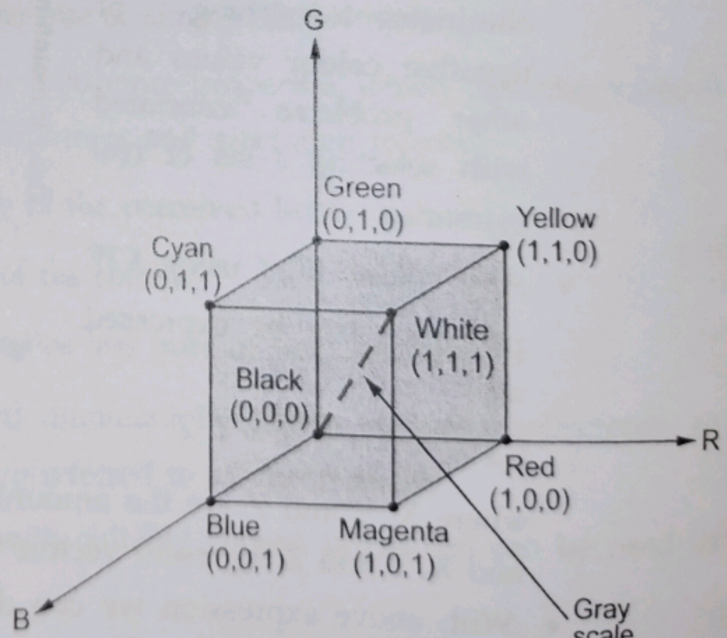


Fig. 11.6.1 The RGB cube

- The vertex of the cube on the axes represent the primary colours and the remaining vertices represent the complementary colour for each of the primary colours.
- The main diagonal of the cube, with equal amounts of each primary represents the gray levels.
- The end at the origin of the diagonal represents black (0, 0, 0) and other end represents white (1,1,1).
- Each colour point within the bounds of the cube is represented as the triple (R, G, B), where value for R, G, B are assigned in the range from 0 to 1.
- As mentioned earlier, it is an additive model.
- Intensities of the primary colours are added to get the resultant colour. Thus, the resultant colour C_λ is expressed in RGB component as,

  $C_\lambda = RR + GG + BB$
- The RGB chromaticity co-ordinates for the CIE RGB colour model are given as R (0.735, 0.265), G (0.274, 0.717), B (0.167, 0.009). The Fig. 11.6.2 shows the colour gamut for the CIE standard RGB primaries.

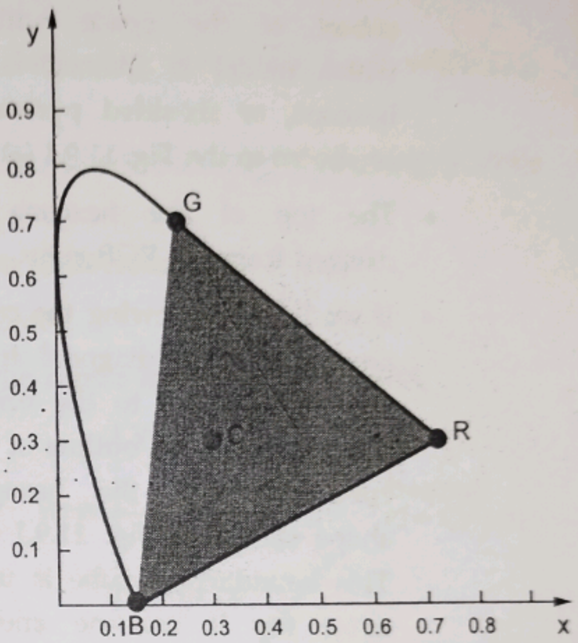


Fig. 11.6.2 Colour gamut for CIE standard RGB primaries

Review Questions

1. *Explain RGB colour model.*
2. *Write a note on RGB colour model.* **AU : Dec.-11, Marks 8**

11.7 YIQ Colour Model

- The YIQ (luminance-inphase-quadrature) model is a recoding of RGB for colour television and is a very important model for colour image processing.
- This model was designed to separate chrominance from luminance. This was a requirement in the early days of colour television when black-and-white sets still were expected to pick up and display what were originally color pictures.
- The Y-channel contains luminance information (sufficient for black-and-white television sets) while the I and Q channels (in-phase and in-quadrature) carried the colour information.

- A colour television set would take these three channels, Y, I and Q and map the information back to R, G and B levels for display on a screen.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.322 \\ 0.212 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- YIQ was formerly used in NTSC (North America, Japan and elsewhere) television broadcasts for historical reasons. This system stores a luminance value with two chrominance values, corresponding approximately to the amounts of blue and red in the colour. It corresponds closely to the YUV scheme used in PAL (Australia, Europe, except France, which uses SECAM) television except that the YIQ colour space is rotated 33° with respect to the YUV colour space.

Review Question

1. *Explain YIQ colour model.*

11.8 CMY Colour Model

AU : May-12

- In this model cyan, magenta and yellow colours are used as primary colours.
- This model is used for describing colour output to hard-copy devices.
- Unlike video monitor, which produce a colour pattern by combining light from the screen phosphors, hard-copy devices such as plotters produce a colour picture by coating a paper with colour pigments.
- The subset of the cartesian co-ordinate system for the CMY model is the same as that for RGB except that white (full light) instead of black (no light) is at the origin.
- Colours are specified by what is removed or subtracted from white light, rather than by what is added to blackness.
- Cyan can be formed by adding green and blue light. Therefore, when white light is reflected from cyan coloured ink, the reflected light does not have red component. That is, red light is absorbed or subtracted, by the ink.
- Magenta ink subtracts the green component from incident light and yellow subtracts the blue component. Therefore, cyan, magenta and yellow are said to be complements of red, green and blue respectively.
- Fig. 11.8.1 shows the cube representation for CMY model.

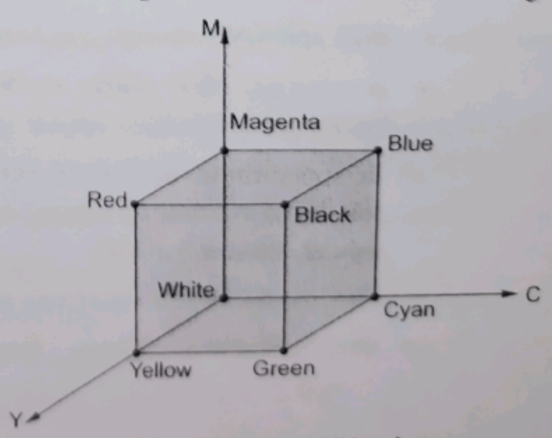


Fig. 11.8.1 The CMY cube

- As shown in the Fig. 11.8.1, point (1,1,1) represents black, because all components of the incident light are subtracted.
- The point (0, 0, 0), the origin represents white light.
- The main diagonal represents equal amount of primary colours, thus the gray colours.
- A combination of cyan and yellow produces green light, because the red and blue components of the incident light are absorbed.
- Other colour combinations are obtained by a similar subtractive process.
- It is possible to get CMY representation from RGB representation as follows,

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- The unit column vector is the RGB representation for white and the CMY representation for black. The conversion from RGB to CMY then can be given as,

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

Review Questions

1. *Explain CMY colour model.*
2. *Compare and contrast between RGB and CMY colour models.* **AU : May-12, Marks 16**
3. *Explain how RGB to CMY conversion is done.*

11.9 HSV Colour Model

AU : Dec.-11, 13, May-13

- RGB and CMY models are hardware oriented models.
- In contrast, HSV colour model is user oriented. It uses colour descriptions that have a more intuitive appeal to a user.
- The colour specification in HSV model can be given by selecting a spectral colour and the amounts of white and black that are to be added to obtain different shades, tints and tones.
- This model uses three colour parameter : hue (H), saturation (S) and value (V).
- Hue distinguishes among colours such as red, green, purple and yellow.

- Saturation refers to how far colour is from a gray of equal intensity. For example, red is highly saturated whereas pink is relatively unsaturated. The value V indicates the level of brightness.
- This model uses cylindrical co-ordinate system and the subset of the space within which model is defined is a hexcone, or six-sided pyramid, as shown in the Fig. 11.9.1 (a).
- The top of the hexcone is derived from the RGB cube.
- If we imagine viewing the cube along the main diagonal from the white vertex to the origin (black), we see an outline of the cube that has the hexagon shape shown in Fig. 11.9.1 (b). This boundary of cube is used as a top if hexcone and it represents various hues.

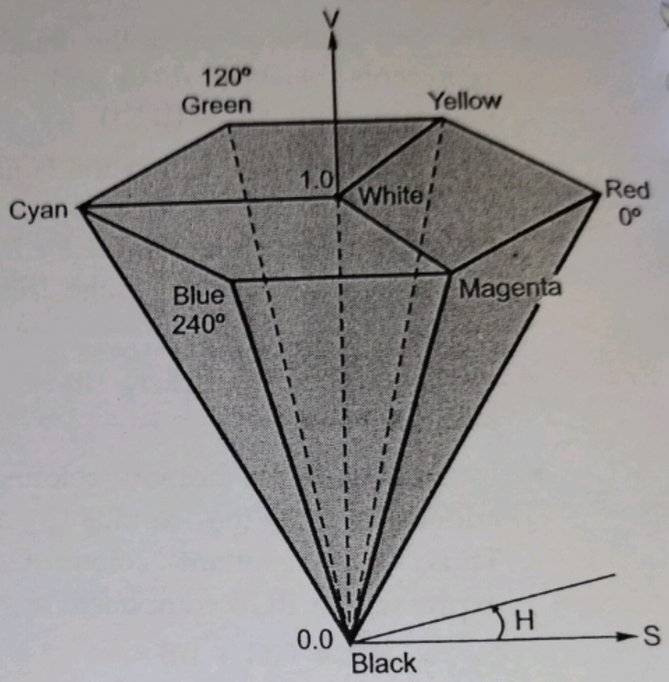
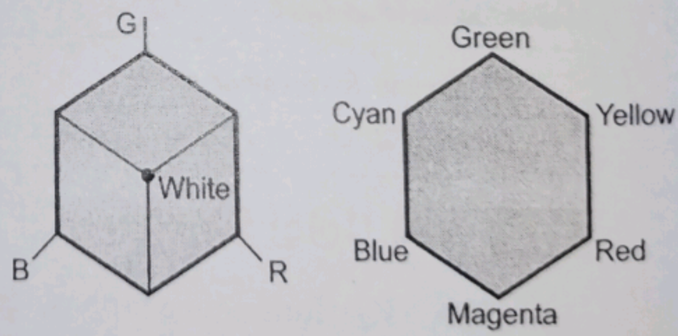


Fig. 11.9.1 The HSV hexcone

- Hue or H, is measured by the angle around the vertical axis, with red at 0 °, green at 120 ° and so on as shown in the Fig. 11.9.1 (a).
- Complementary colours in the HSV hexcone are 180 ° apart saturation parameter varies from 0 to 1. Its value is the ratio ranging from 0 on the centre line (V axis) to 1 on the triangular sides of the hexcone.
- The value V varies from 0 at the apex of the hexcone to 1 at the top. The apex represents black.



(a) RGB colour cube **(b) Colour hexagon**

Fig. 11.9.2 Top of hexcone

- At the top of the hexcone, colours have their maximum intensity.

- When V = 1 and S = 1, we have the pure hues. For example, pure red is at H = 0, V = 1 and S = 1, pure green is at H = 120, V = 1 and S = 1, pure blue is at H = 240, V = 1 and S = 1 and so on.
- The required colour can be obtained by adding either white or black to the pure hue.
- Black can be added to the selected hue by decreasing the setting for V while S is held constant.
- On the other hand, white can be added to the selected hue by decreasing S while keeping V constant.
- To add some black and some white we have to decrease both V and S.
- The point S = 0 and V = 1 we have white colour.
- The intermediate values of V for S = 0 (on the centre line) are gray shades.
- When S = 0, the value of H is irrelevant.
- When S is not zero, H is relevant.
- At the apex V co-ordinate is 0. At this point, the values of H and S are irrelevant.
- Fig. 11.9.3 shows the cross sectional plane of the HSV hexcone. This plane represents the colour concepts associated with the terms shades, tints and tones.
- As shown in Fig. 11.9.3, we can add Black colour to pure hue to produce different shades of the colour.
- White colour to pure hue to produce different tints of the colour.
- Both white and black colours to pure hue to produce tones of the colour.

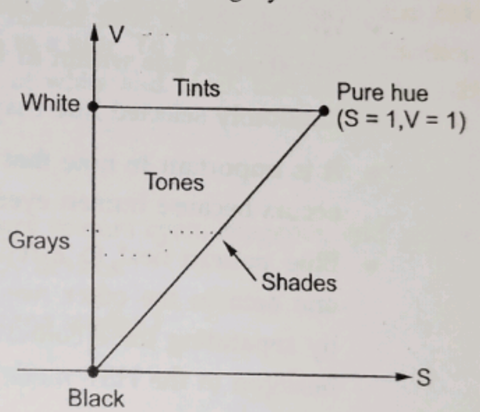


Fig. 11.9.3 Cross sectional plane of the HSV showing tints, tones and shades

Example 11.9.1 *Write a procedure for HSV to RGB conversion.*

Solution : The procedure to obtain transformation from HSV to RGB is as follows :

```
void HSV_To_RGB (double *r, double *g,double *b,double h, double s, double v)
/* Given: h in [0,360], s and v in [0.1]. */
/*Desired : r, g, b, each in [0, 1]. */
{
double f, p, q, t;
int i;
if (s == 0.0) {        /* The color is on the black-and-white center line i.e. grayscale */
      *r =    v;               /* This is the achramatic case.*/
```

```
        *g =    v;
        *b =    v;
}
else {
if      (h      ==      360.0)          /* 360 degrees is equivalent to 0 degrees. */
        h       =       0.0;
        h /     =       60.0;           /* h is now in [0,6]. */
        i       =       floor (h);      /* Floor returns the largest integer <= h */
        f       =       h - i ;         /* f is the fractional part of h. */
        p       =       v * (1.0 - s) ;
        q       =       v * (1.0 - (s * f));
        t       =       v * (1.0 - (s * (1.0 - f)));
        switch (i) {
        case 0 :* r = v; *g = t; *b = p; break ;
        case 1 :* r = q; *g = v; *b = p; break ;
        case 2 :*r = p; *g = v; *b = t; break ;
        case 3 :*r = p; *g = q; *b = v; break ;
        case 4 :*r = t; *g = p; *b = v; break ;
        case 5 :*r = v; *g = p; *b = q; break ;
        }
} /* Choromatic case */
} /* HSV_To_RGB */
```

Review Questions

1. *Explain HSV colour model.*
2. *Compare RGB and HSV colour model.*
3. *Write a note on HSV colour model.* **AU : Dec.-11, Marks 8**
4. *Briefly explain different colour models.* **AU : May-13, Dec.-13, Marks 16**

11.10 HLS Colour Model

AU : May-13

- Another model based on intuitive colour parameters is the HLS colour model used by Tektronix.
- The three colour parameters in this model are : hue (H), lightness (L) and saturation (S). It is represented by double hexcone, as shown in the Fig. 11.10.1.
- The hue specifies the angle around the vertical axis of the double hexcone.
- In this model, H = 0° corresponds to blue.
- The remaining colours are specified around the perimeter of the hexcone in the same order as in the HSV model.
- Magenta is at 60°, red is at 120° and yellow is located at H = 180°.
- Complementary colours are 180° apart on the double hexcone.

- The vertical axis in this model represents the lightness, L.
- At L = 0, we have black and at L = 1, we have white.
- In between value of L we have gray levels.
- The saturation parameters S varies from 0 to 1 and it specifies relative purity of a colour.
- At S = 0, we have the gray scale and at S = 1 and L = 0.5, we have maximum saturated (pure) hue.
- As S decrease, the hue saturation decreases i.e. hue becomes less pure.
- In HLS model a hue can be selected by selecting hue angle H and the desired shade, tint or tone can be obtained by adjusting L and S.
- The colours can be made lighter by increasing L and can be made darker by decreasing L.
- The colours can be moved towards gray by decreasing S.] 2

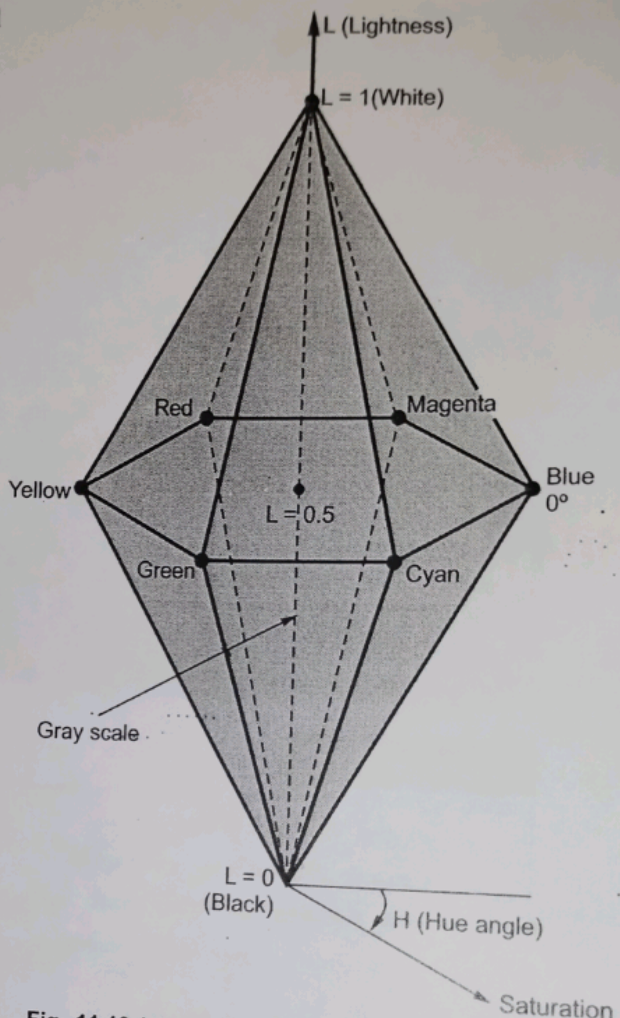


Fig. 11.10.1 Double-hexcone HLS colour model

Review Questions

1. *Explain HLS colour model.*
2. *Draw the colour model HLS double cone.* **AU : May-13, Marks 2**