# UNIT – IV
# ILLUMINATION AND COLOUR MODELS
## PART-A

**1.What is a color model?**
A color model is a method for explaining the properties or behavior of color within some particularcontext. Example: XYZ model, RGB model.

**2. Define intensity of light, brightness and hue.**
Intensity is the radiant energy emitted per unit time, per unit solid angle, and per unit projected area ofsource. Brightness is defined as the perceived intensity of the light. The perceived light has a dominantfrequency (or dominant wavelength). The dominant frequency is also called as hue or simply as color.

**3. What is purity of light? Define purity or saturation.**
Purity describes how washed out or how “pure” the color of the light appears. Pastels and pale colors aredescribed as less pure. Purity describes how washed out or how "pure" the color of the light appears.

**4. Define chromacity and intensity.**
The term chromacity is used to refer collectively to the two properties describing color characteristics:
purity and dominant frequency.Intensity is the radiant energy emitted per unit time, per unit solid angle,and p:r unit projected area of the source.

**5. Define complementary colors and primary colors**.
If the two color sources combine to produce white light, they are referred to as 'complementary colors. Examples of complementary color pairs are red and cyan, green and magenta, and blue and yellow.Thetwo or three colors used to produce other colors in a color model are referred to as primary colors.

**6. State the use of chromaticity diagram.**
Comparing color gamuts for different sets of primaries.Identifying complementary colors.Determiningdominant wavelength and purity of a given color.

**7. How is the color of an object determined?**
When white light is incident upon an object, some frequencies are reflected and some are absorbed by theobject. The combination of frequencies present in the reflected light determines what we perceive as thecolor of the object.

**8. Explain about CMY model.**
A color model defined with the primary colors cyan, magenta and yellow is useful for describing coloroutput to hard copy devices.

**9. How will you convert from YIQ to RGB color model? (AU MAY/JUNE 2012 IT)**
Conversion from YIQ space to RGB space is done with the inverse matrix transformation:
R1.000 0.956 0.620 Y
G = 1.000 −0.272 −0.647 I
B1.000 −1.108 1.705 Q

**10. What isIlumination and the Ilumination models?**
The transport of light from a source to a point via direct and indirect paths is called Ilumination.
Illumination Models:
Empirical - approximations to observed light properties
Physically based - applying physics properties of light and its interactions with matter

**11. State the difference between CMY and HSV color models. (AU NOV/DEC 2012)**

| CMY Model | HSV Model |
|---|---|
| A color model defined with the primary colors cyan, magenta and yellow (CMY) is useful for describing color output to hard-copy devices. | The HSV model uses color descriptors that have a more natural appeal to the user. Color parameters in this model are hue (H), saturation (S) and value(V). |
| Hard-copy devices such as plotters produce a colorpicture by coating a paper with color pigments. | To give color specification, a user selects a spectralcolor and the amounts of black and white that are tobe added to obtain different shades, tints and tones. |

**12. What are subtractive colors? (AU MAY/JUNE 2012)**
In CMY color model, colors are seen by reflected light a subtractive process. Cyan can be formed byadding green and blue light. Therefore, when white light is reflected from cyan-colored ink, the reflectedlight must have no red component. The red light is absorbed or subtracted by the ink. Similarly magentaink subtracts the green component from incident light and yellow subtracts the blue component.

**13.What are the properties of light source?**
Color : We usually *assume* the light has one wavelength
Shape : Point light source - approximate the light source as a 3D point in space. Light rays emanate in all directions. Good for small light sources (compared to the scene). Far away light sources

**14.What is halftone pattern and dithering?**
The process of generating a binary pattern of black and white dots from an image is termed halftoning**.**
Half tone Pattern is a rectangular pixel regions used to approximate the halftone production
Dithering refers to techniques for approximating halftone without reducing resolution

**15.What are the various sources of Ilumination?**

1. Direct
2. Indirect
3. Global
4. Local

**16.What is Ambient light?**

Ambient light:

• Uniform from all directions

• $K\alpha$ measures reflectivity of surface for diffuse light (values in the range: 0-1)

I(Intensity ofambient light) = $K\alpha\ I\alpha$

**17.What is meant by chromaticity?**

Chromaticity is an objective specification of the quality of a color regardless of its luminance. Chromaticity consists of two independent parameters, often specified as hue (h) and colorfulness (s), where the latter is alternatively called saturation, chroma, intensity, or excitation purity.

**18. What is meant by image formation and their elements?**

In computer graphics we form images which are generally two dimensional using a process analogous to how images are formed by physical imaging systems.

The elements are

- Objects
- Viewer
- Light Source

**19.What is color and shading?**

For each point in our image we need to determine its color which is a function of the objects surface color, its texture, the relative positions of light sources, and the indirect reflection of light off of other surfaces in the scene.

**20.What is Additive color and Subtractive color system?**

Media that combine emitted lights to create the sensation of a range of colors are using the additive color system. Typically, the primary colors used are red, green, and blue.

Media that use reflected light and colorants to produce colors are using the subtractive color method of color mixing. Eg. CMYK color model

## PART - B

1. **Explain RGB color model in detail.(AU NOV/DEC 2012)**

Color model-basic definition

RGB color model

Colors are displayed based on the theory of vision ( eyes perceive colors through the stimulation of three visual pigments in the cones of the retina)

It is an additive model

Uses Red, Green and Blue as primary colors

Represented by an unit cube defined on the R, G and B axes

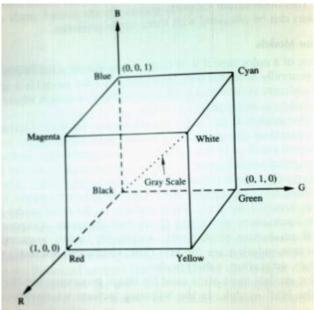
The origin represents black and the vertex with coordinates(1,1,1) represents white

Any color $C\lambda$ can be represented as RGB components

as $C\lambda = RR + GG + BB$

RGB color components

RGB color model defined with color cube




2. **Write notes on RGB and HSV color models.(AU NOV/DEC 2011)**

Color model-basic definition

RGB color model

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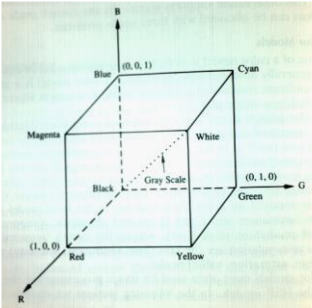
Any color $C\lambda$ can be represented as RGB components as

$C\lambda = RR + GG + BB$

RGB color components

RGB color model defined with color cube




HSV color model

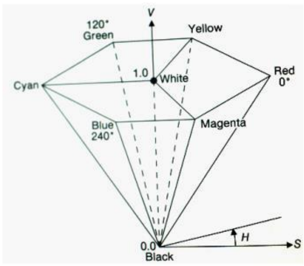
Color parameters-hue (H) saturation (S) and value (V)

The HSV hexcone

Cross section of the HSV hexcone

Color parameters used are
hue
saturation
value

Color is described by adding either black or white to the pure hue
Adding black decreases V while S remains constant
Adding white decreases S while V remains constant
Hue is represented as an angle about vertical axis ranging from 0 degree to 360 degrees S varies from 0 to 1
V varies from 0 to 1




**3. Compare and contrast between RGB and CMY color models.(AU MAY/JUNE 2012)**

RGB color model
Color model-basic definition
RGB color model
Colors are displayed based on the theory of vision ( eyes perceive colors through the stimulation of three visual pigments in the cones of the retina)
It is an additive model
Uses Red, Green and Blue as primary colors
Represented by an unit cube defined on the R, G and B axes
The origin represents black and the vertex with coordinates(1,1,1) represents white Any color Cλ can be represented as RGB components as

$$C\lambda = RR + GG + BB$$

RGB color components
RGB color model defined with color cube
CMY color model
Basic colors
The CMY color model defined with subtractive process inside a unit cube
Based on subtractive process
Primary colors are cyan , magenta , yellow
Useful for describing color output to hard copy devices
Color picture is produced by coating a paper with color pigments
The printing process generates a color print with a collection of four ink dots ( one each for the primary & one for black)
RGB to CMY transformation matrix-CMY to RGB transformation matrix

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

4. **Explain in detail about YIQ color** model.

- Y is luminance

Sometimes you have to use it

– video input/output
Makes sense in image compression:
– better compression ratio if changing class Y before compression
– High bandwidth for Y
– Small bandwidth for chromaticity
– Lab is fine for that too

Y = 0.257*R + 0.504*G + 0.098*B + 16

• YIQ color space (Matlab conversion function: rgb2ntsc):

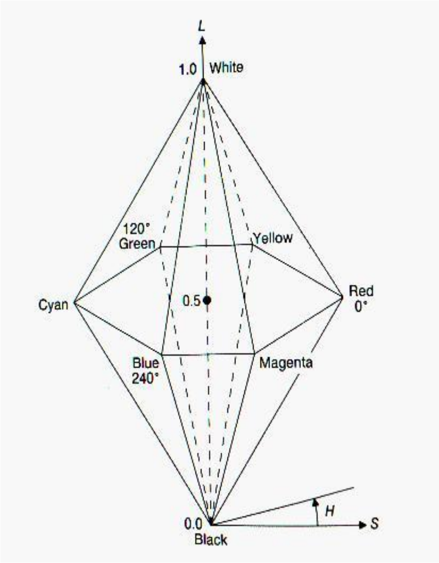
$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

**5. Explain in detail about HLS color model.**

HSL color obviously has the parameters H, S and L, or Hue, Saturation and Lightness. **Hue** indicates the color sensation of the light, in other words if the color is red, yellow, green, cyan, blue, magenta, ... This representation looks almost the same as the visible spectrum of light, except on the right is now the color magenta (the combination of red and blue), instead of violet (light with a frequency higher than blue):

**Saturation** indicates the degree to which the hue differs from a neutral gray. The values run from 0%, which is no color, to 100%, which is the fullest saturation of a given hue at a given percentage of illumination. The more the spectrum of the light is concentrated around one wavelength, the more saturated the color will be.

**Lightness** indicates the illumination of the color, at 0% the color is completely black, at 50% the color is pure, and at 100% it becomes white. In HSL color, a color with maximum lightness (L=255) is always white, no matter what the hue or saturation components are. Lightness is defined as (maxColor+minColor)/2 where maxColoris the R, G or B component with the maximum value, and minColor the one with the minimum value.




**6. Explain in detail about HSV color model**

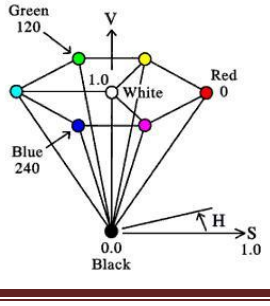
Another way to characterize a color is in terms of the HSV model.

- The *hue* (H) of a color refers to which pure color it resembles. All tints, tones and shades of red have the same hue.

Hues are described by a number that specifies the position of the corresponding pure color on the color wheel, as a fraction between 0 and 1. Value 0 refers to red; 1/6 is yellow; 1/3 is green; and so forth around the color wheel.

- The *saturation* (S) of a color describes how white the color is. A pure red is fully saturated, with a saturation of 1; tints of red have saturations less than 1; and white has a saturation of 0.
- The *value* (V) of a color, also called its *lightness*, describes how dark the color is. A value of 0 is black, with increasing lightness moving away from black.

This diagram, called the *single-hexcone model of color space*, can help you visualize the meaning of the H, S, and V parameters.



- The outer edge of the top of the cone is the color wheel, with all the pure colors. The H parameter describes the angle around the wheel.
- The S (saturation) is zero for any color on the axis of the cone; the center of the top circle is white. An increase in the value of S corresponds to a movement away from the axis.
- The V (value or lightness) is zero for black. An increase in the value of V corresponds to a movement away from black and toward the top of the cone.

**7. Explain in detail about CMY color model.**

CMY color model

The CMY color model defined with subtractive process inside a unit cube

- Based on subtractive process
- Primary colors are cyan , magenta , yellow
- Useful for describing color output to hard copy devices
- Color picture is produced by coating a paper with color pigments
- The printing process generates a color print with a collection of four ink dots ( one each for the primary & one for black)

RGB to CMY transformation matrix-CMY to RGB transformation matrix

**8. Explain in detail the various Illuminations models.**

Illumination Models & Surface-Rendering Methods

- ***Illumination model*** or a ***lighting model*** is the model for calculating light intensity at a single surface point.
- ***Surface rendering*** is a procedure for applying a lighting model to obtain pixel intensities for all the projected surface positions in a scene.

Given the parameters:

- the optical properties of surfaces (opaque/transparent, shiny/dull, surface-texture);
- the relative positions of the surfaces in a scene;
- the color and positions of the light sources;
- the position and orientation of the viewing plane.

Illumination models calculate the intensity projected from a particular surface point in a specified viewing direction.

- Basic Illumination Models

Ambient Light

Diffuse Reflection

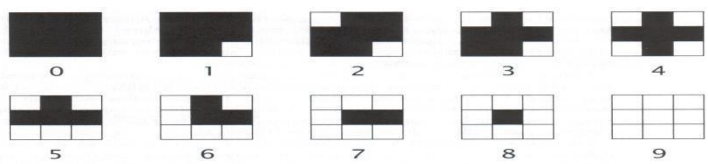
Specular Reflection & Phong Model

Combine Diffuse & Specular Reflections with Multiple Light Sources

- When we view an opaque nonluminous object, we see reflected light from the surfaces of the object.
- The total reflected light is the sum of the contributions from ***light sources*** and other reflecting surfaces in the scene.
- Light sources = ***light-emitting sources***.
- Reflecting surfaces = ***light-reflecting sources***.

**9. Explain in detail about halftone patterns and dithering techniques.**

- The process of generating a binary pattern of black and white dots from an image is termed **halftoning.** • In traditional newspaper and magazine production, this process is carried out photographically by projection of a transparency through a 'halftone screen' onto film.
- The screen is a glass plate with a grid etched into it.
- Different screens can be used to control the size and shape of the dots in the halftoned image.
- A fine grid, with a 'screen frequency' of 200-300 lines per inch, gives the image quality necessary for magazine production.
- A screen frequency of 85 lines per inch is deemed acceptable for newspapers.
- A simple digital halftoning technique known as **patterning** involves replacing each pixel by a pattern taken from a 'binary font'.
- Figure 5. 1 shows such a font, made up of ten 3 x 3 matrices of pixels. • This font can be used to print an image consisting of ten grey levels.



- A pixel with a grey level of 0 is replaced by a matrix containing no white pixels; a pixel with a grey level of 1 is replaced by a matrix containing a single white pixel; and so on.
- Note that, since we are replacing each pixel by a 3 x 3 block of pixels, both the width and the height of the image increase by a factor of 3.
- Figure 5. 2 shows an example of halftoning using the binary font depicted in Figure 5. 1.

Another technique for digital halftoning is **dithering.**

- Dithering can be accomplished by thresholding the image against a **dither matrix.**
- The first two dither matrices, rescaled for application to 8-bit images, are

$$\mathbf{D}_1 = \begin{bmatrix} 0 & 128 \\ 192 & 64 \end{bmatrix},$$

$$\mathbf{D}_2 = \begin{bmatrix} 0 & 128 & 32 & 160 \\ 192 & 64 & 224 & 96 \\ 48 & 176 & 16 & 144 \\ 240 & 112 & 208 & 80 \end{bmatrix}.$$

- The elements of a dither matrix are thresholds.
- The matrix is laid like a tile over the entire image and each pixel value is compared with the corresponding threshold from the matrix.
- The pixel becomes white if its value exceeds the threshold or black otherwise.
- This approach produces an output image with the same dimensions as the input image, but with less detail visible.

Algorithm to halftone an image using a dither matrix.

```
for  all x & y do
if f(x,y) > m(x,y) then
g(x,y) = white
    else
        g(x,y) = black
    end if
End for
```

**10. Explain in detail the RGB chromaticity diagrams and XYZ chromaticity diagrams.**

Chromaticity is an objective specification of the quality of a color regardless of its luminance. Chromaticity consists of two independent parameters, often specified as hue (h) and colorfulness (s), where the latter is alternatively called saturation, chroma, intensity or excitation purity. This number of parameters follows from trichromacy of vision of most humans, which is assumed by most models in color science.

**RGB chromaticity**

An RGB color space is any additive color space based on the RGB color model. A particular RGB color space is defined by the three chromaticities of the red, green, and blue additive primaries, and can produce any chromaticity that is the triangle defined by those primary colors. The complete specification of an RGB color space also requires a white point chromaticity and a gamma correction curve. RGB is an abbreviation for red–green–blue.