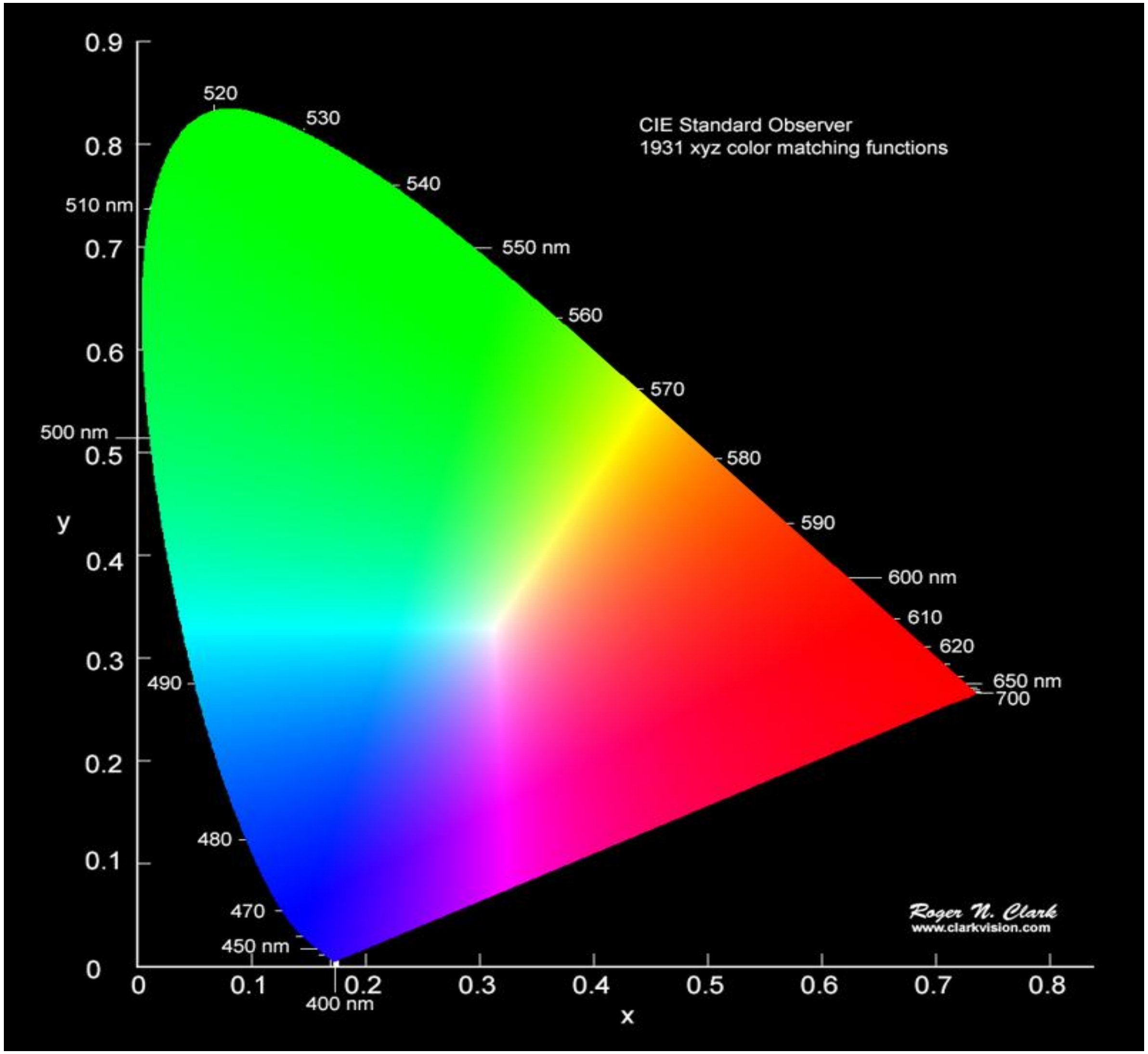
Unit: 4

Light, Color, Shading and Hidden Surfaces

CIE Chromaticity Diagram

- A diagram was developed by the Commission International L’ Eclairage(CIE) which is graphically points the eyes response to colors.
- Every point represents some color.
- The diagram is designed in such a way that all colors on a line between two color points may be produced by mixing the light of the end point colors.
- Points along the curve are the pure colors in the electromagnetic spectrum, labeled according to wavelength in nanometers from the red end to the violet end of the spectrum.
- White light position in the diagram is represented by point V.



CIE Standard Observer
1931 xyz color matching functions
520
530
540
550 nm
560
570
580
590
600 nm
610
620
650 nm
700
510 nm
500 nm
490
480
470
450 nm
400 nm
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
y
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x
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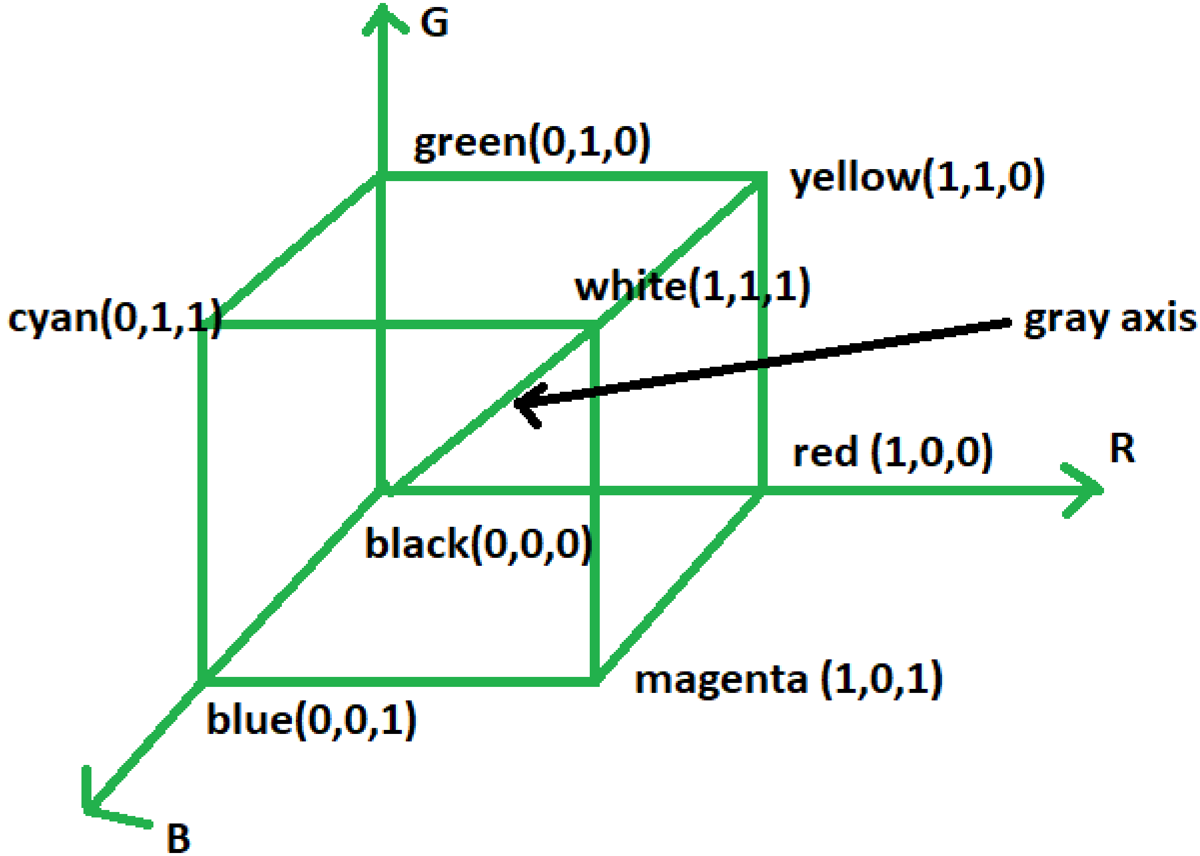
Color Models

1. RGB color model
2. CMY color model
3. HSV color model

RGB color model

- The RGB color model is one of the most widely used color representation method in computer graphics.
- It use a color coordinate system with three primary colors: R(red), G(green), B(blue)
- Each primary color can take an intensity value ranging from 0(lowest) to 1(highest).
- Mixing these three primary colors at different intensity levels produces a variety of colors.
- The collection of all the colors obtained by such a linear combination of red, green and blue forms the cube shaped RGB color space.

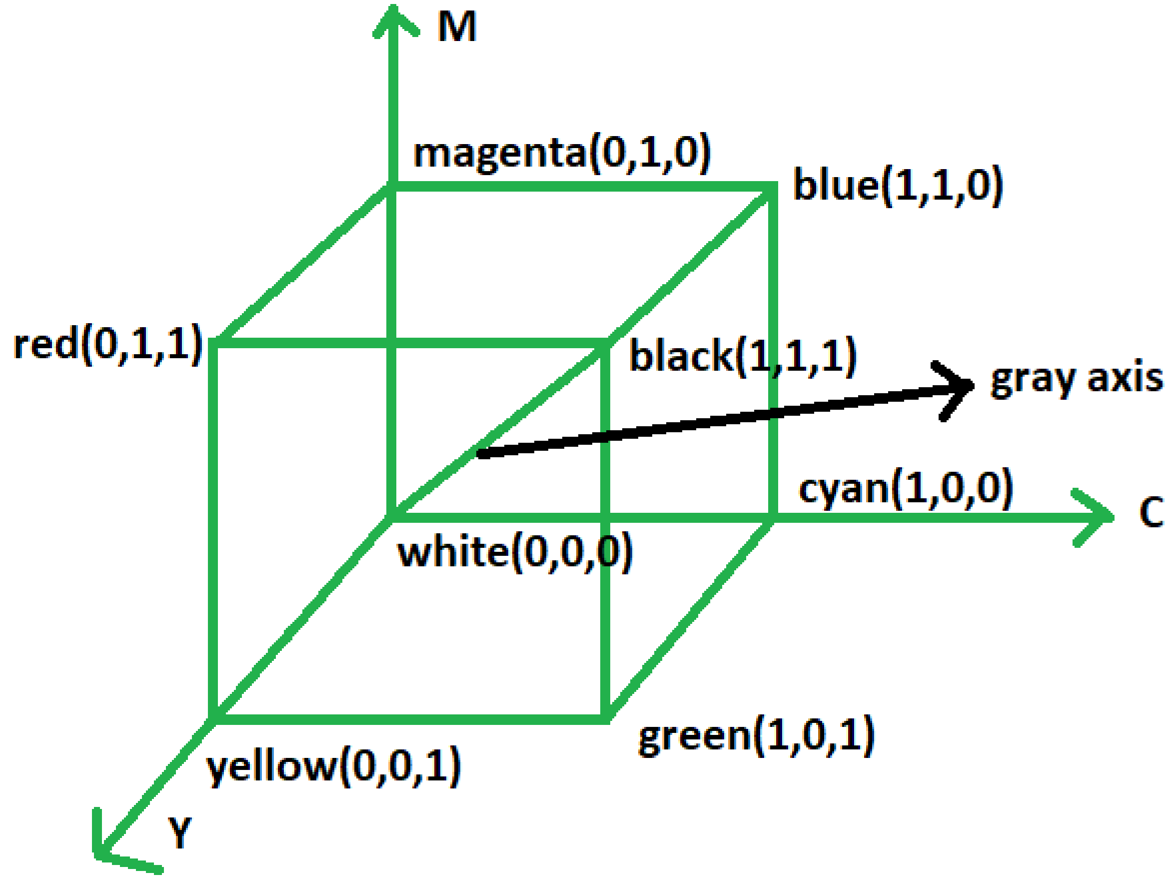


- The RGB color model is an additive color model in which red, green and blue light are added together in various ways to reproduce a broad array of colors.
- The name of the model comes from the initials of the three additive primary colors, red, green, and blue.

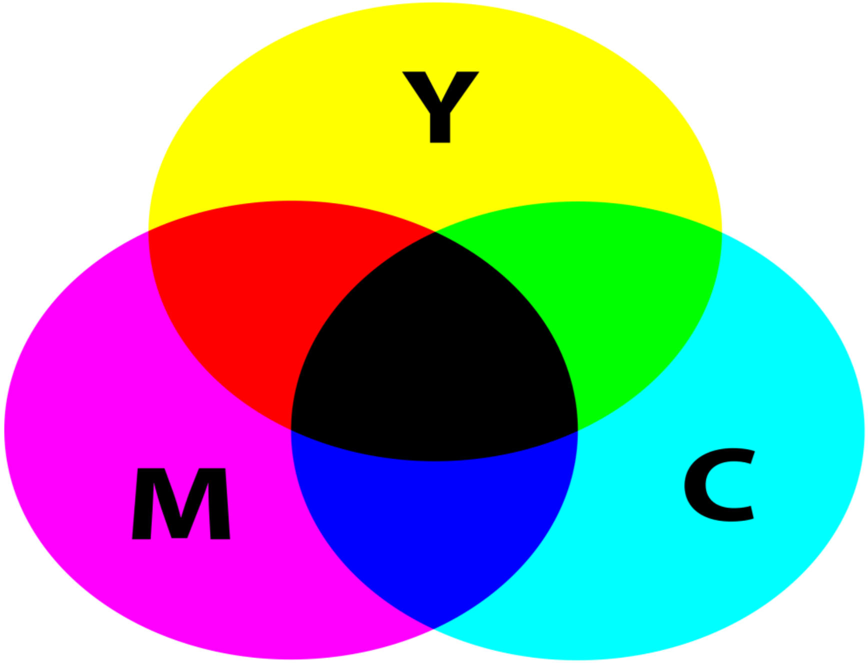
- The corner of RGB color cube that is at the origin of the coordinate system corresponds to black, whereas the corner of the cube that is diagonally opposite to the origin represents white.
- The diagonal line connecting black and white corresponds to all the gray colors between black and white, which is also known as **gray axis**.
- In the RGB color model, an arbitrary color within the cubic color space can be specified by its color coordinates: (r, g,b).

CMY Color Model

- **Cyan, magenta and yellow** are the secondary colors of light and the primary colors of pigments.
- This means, if white light is shined on a surface coated with cyan pigment, no red light is reflected from it.
- Cyan subtracts red light from white light.
- Unlike the RGB color model, CMY is **subtractive**, meaning higher values are associated with darker colors rather than lighter ones.



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



- Devices that deploy pigments to color paper or other surfaces use the CMY color model, e.g. printers and copiers.
- C = 1 - R
- M = 1 - G
- Y = 1 - B

HSV Color Model

- HSV – (hue, saturation, value), also known as HSB (hue, saturation, brightness), is often used by artists because it is often more natural to think about a color in terms of hue and saturation than in terms of additive or subtractive color components.
- HSV is a transformation of an RGB color space, and its components and colorimetry are relative to the RGB color space from which it was derived.
- **HSV** is a cylindrical color **model** that remaps the RGB primary colors into dimensions that are easier for humans to understand.

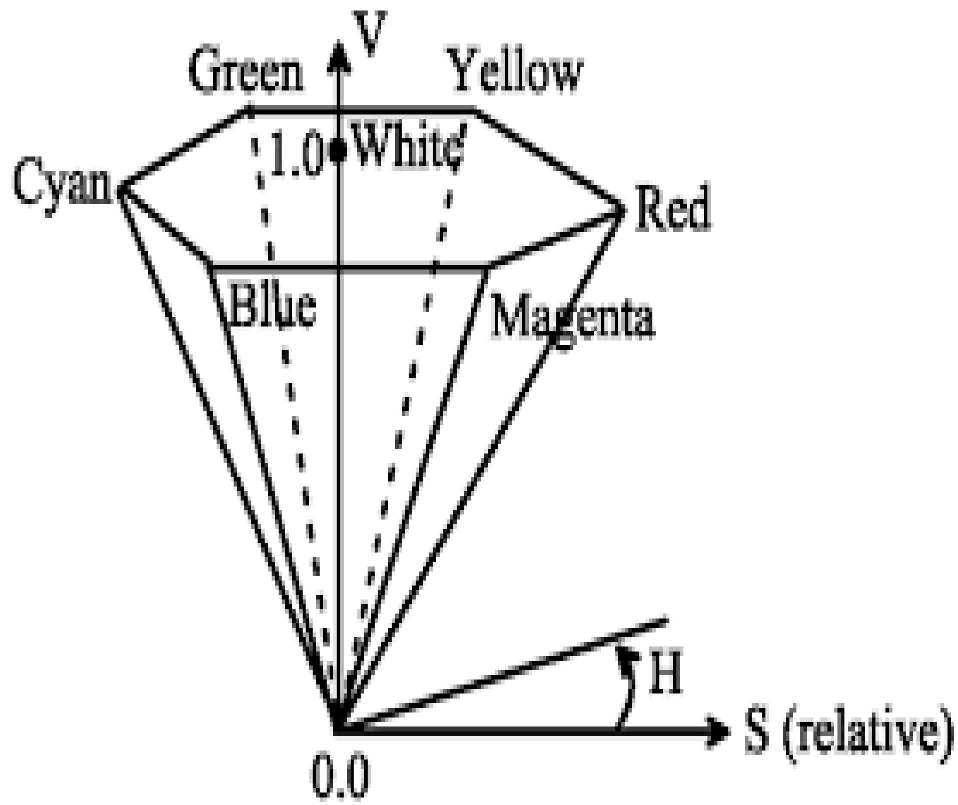
- The HSV color wheel sometimes appears as a cone or cylinder, but always with these three components:
- **HUE**
- Hue is the color portion of the model, expressed as a number from 0 to 360 degrees:
- **Red** falls between 0 and 60 degrees.
- **Yellow** falls between 61 and 120 degrees.
- **Green** falls between 121 and 180 degrees.
- **Cyan** falls between 181 and 240 degrees.
- **Blue** falls between 241 and 300 degrees.
- **Magenta** falls between 301 and 360 degrees.

SATURATION

- Saturation describes the amount of gray in a particular color, from 0 to 100 percent.
- Reducing this component toward zero introduces more gray and produces a faded effect.
- Sometimes, saturation appears as a range from 0 to 1, where 0 is gray, and 1 is a primary color.

VALUE (OR BRIGHTNESS)

- Value works in conjunction with saturation and describes the brightness or intensity of the color, from 0 to 100 percent, where 0 is completely black, and 100 is the brightest and reveals the most color.

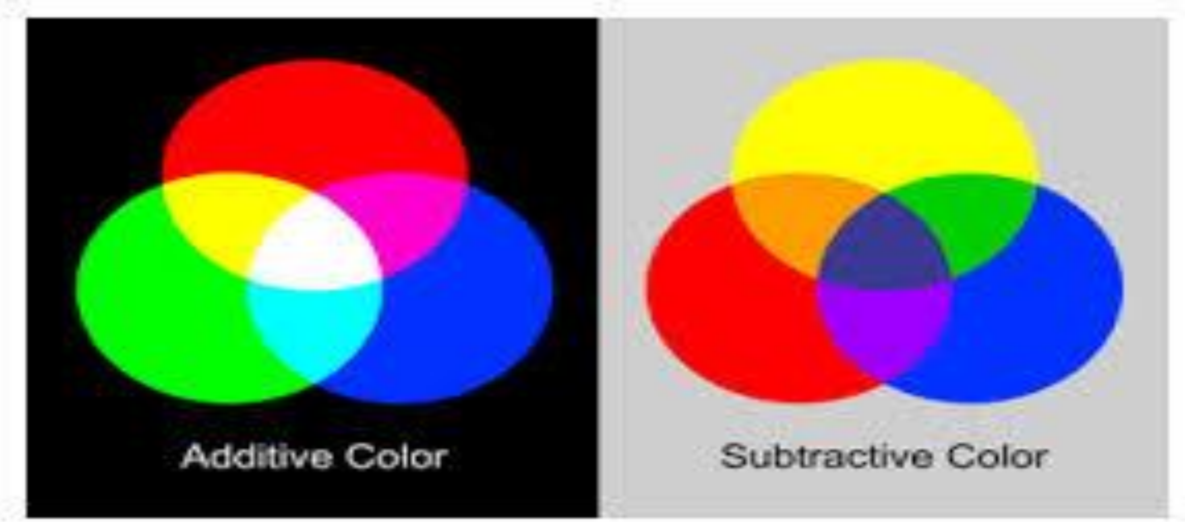


V
Green
Yellow
1.0
White
Cyan
Red
Blue
Magenta
H
S (relative)
0.0

Color Selection

Models for color mixing:

1. **Subtractive color**
2. **Additive color**



Illumination Models

- A model for the interaction of light with a surface is called an **illumination model**.
- **Illumination model**, also known as Shading **model** or Lightning **model**, is used to calculate the intensity of light that is reflected at a given point on surface.
- **There are three factors on which lightning effect depends on:**

- **Light Source :**
  Light source is the light emitting source. There are three types of light sources:
  - **Point Sources –** The source that emit rays in all directions (A bulb in a room).
  - **Parallel Sources –** Can be considered as a point source which is far from the surface (The sun).
  - **Distributed Sources –** Rays originate from a finite area (A tubelight).

- Their position, electromagnetic spectrum and shape determine the lightning effect.

Surface :

- When light falls on a surface part of it is reflected and part of it is absorbed.
- Now the surface structure decides the amount of reflection and absorption of light.
- The position of the surface and positions of all the nearby surfaces also determine the lightning effect.

Observer :

The observer's position and sensor spectrum sensitivities also affect the lightning effect.

1. Ambient Illumination :

- Assume you are standing on a road, facing a building with glass exterior and sun rays are falling on that building reflecting back from it and the falling on the object under observation.
- This would be **Ambient Illumination**. In simple words, Ambient Illumination is the one where source of light is indirect.
- The reflected intensity I_{amb} of any point on the

$$I_{amb} = K_a I_a$$

Where, I_a : ambient light intensity
K_a : surface ambient reflectivity, value of K_a varies from 0 to 1

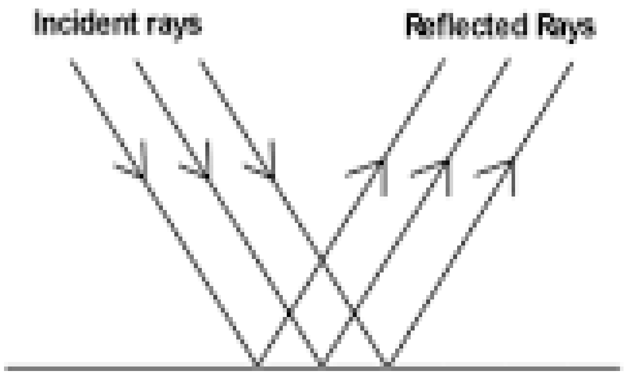
2. Diffuse Reflection :

- Diffuse reflection occurs on the surfaces which are rough or grainy.
- In this reflection the brightness of a point depends upon the angle made by the light source and the surface.
- The reflected intensity I_{diff} of a point on the surface is:

$$I_{diff} = K_d I_p \cos(\theta) = K_d I_p (N \cdot L)$$

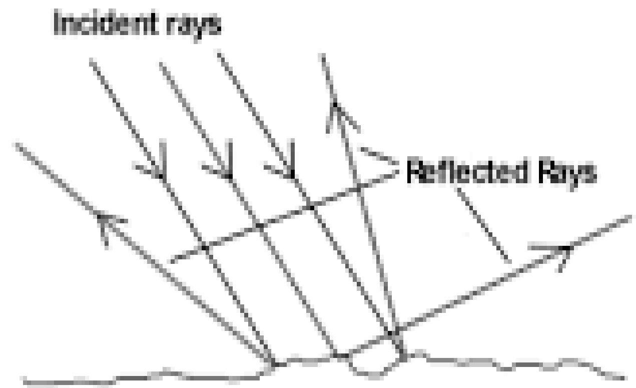
Where, I_p : the point light intensity
K_d : the surface diffuse reflectivity, value of K_d varies from 0 to 1
N : the surface normal
L : the light direction

Regular Reflection



Eg. plane mirror or any other surface that produces a reflected image.

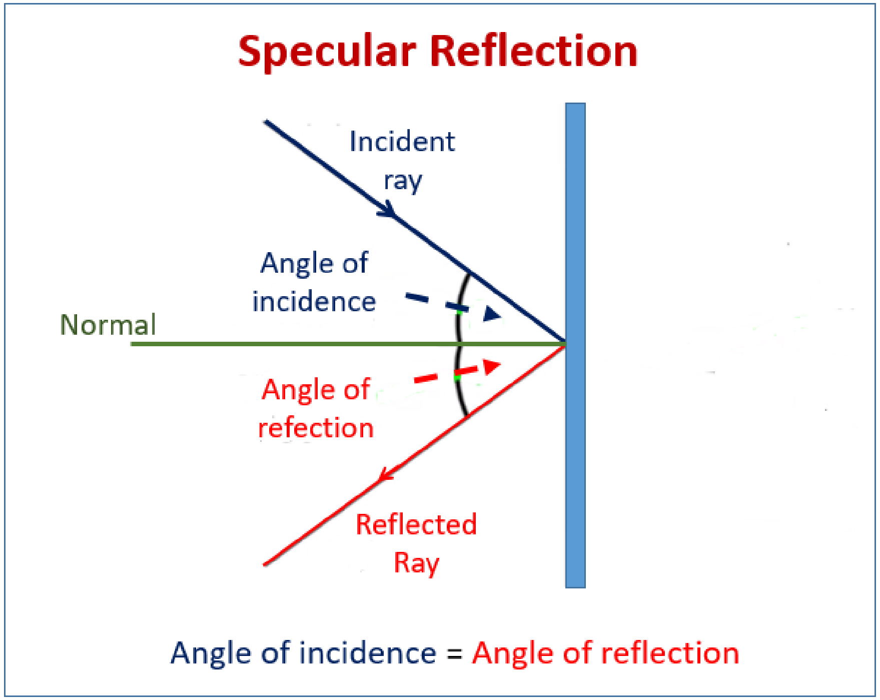
Diffuse Reflection



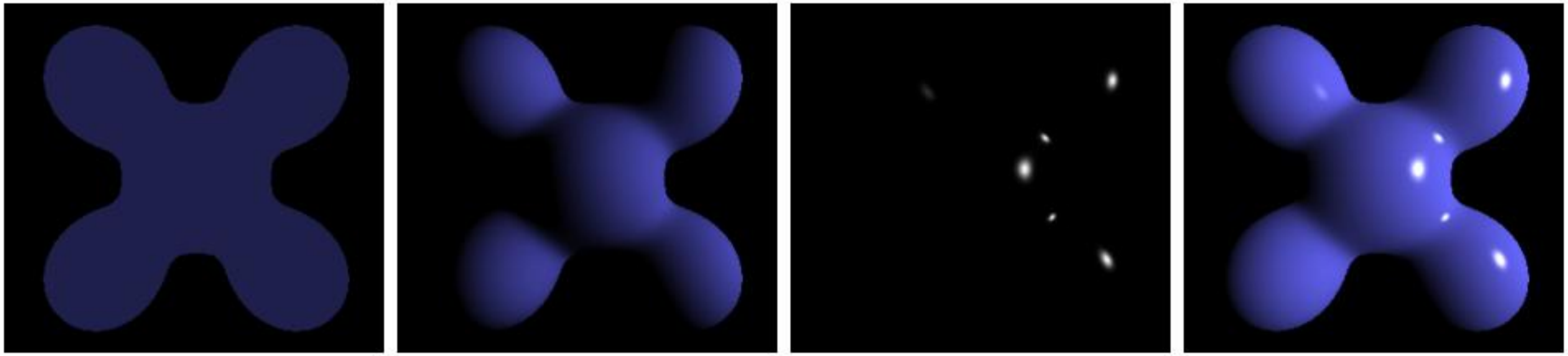
This is like any surface that we can see but does not reflect an image

3. Specular Reflection :

When light falls on any shiny or glossy surface most of it is reflected back, such reflection is known as Specular Reflection.



- **Phong Model:**
- Phong reflection is an empirical model of local illumination.
- It describes the way a surface reflects light as a combination of the diffuse reflection of rough surfaces with the specular reflection of shiny surfaces.
- It is based on Phong's informal observation that shiny surfaces have small intense specular highlights, while dull surfaces have large highlights that fall off more gradually.
- The model also includes an *ambient* term to account for the small amount of light that is scattered about the entire scene.



Ambient + Diffuse + Specular = Phong Reflection

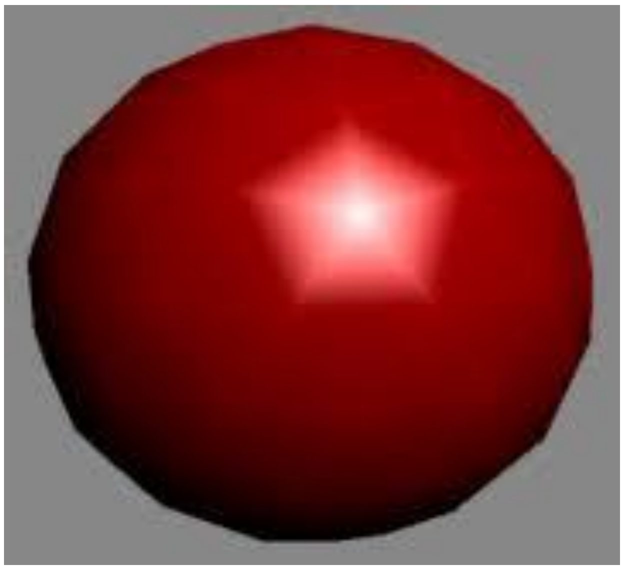
Shading Algorithm

1. Gouraud Shading
2. Phong Shading
3. Halftone shading

Gouraud Shading

- This Intensity-Interpolation scheme, developed by Gouraud and usually referred to as Gouraud Shading, renders a polygon surface by linear interpolating intensity value across the surface.
- Intensity values for each polygon are coordinate with the value of adjacent polygons along the common edges, thus eliminating the intensity discontinuities that can occur in flat shading.
- Each polygon surface is rendered with Gouraud Shading by performing the following calculations:

1. Determining the average unit normal vector at each polygon vertex.
2. Apply an illumination model to each vertex to determine the vertex intensity.
3. Linear interpolate the vertex intensities over the surface of the polygon.



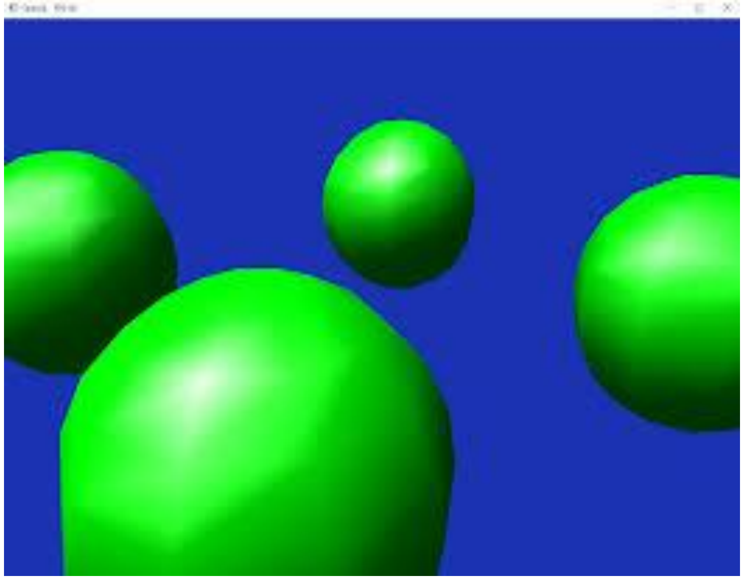


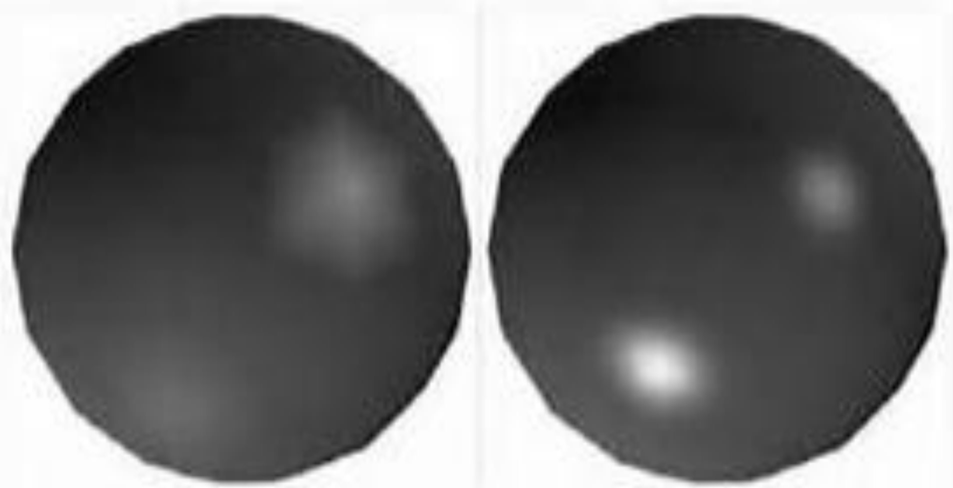
Fig: Gouraud shading

Phong Shading

- A more accurate method for rendering a polygon surface is to interpolate the normal vector and then apply the illumination model to each surface point.
- This method developed by Phong Bui Tuong is called Phong Shading or normal vector Interpolation Shading.
- It displays more realistic highlights on a surface and greatly reduces the Match-band effect.

- A polygon surface is rendered using Phong shading by carrying out the following steps:

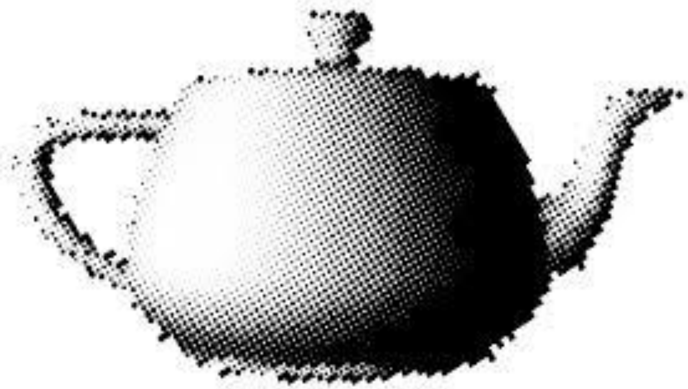
1. Determine the average unit normal vector at each polygon vertex.
2. Linearly & interpolate the vertex normals over the surface of the polygon.
3. Apply an illumination model along each scan line to calculate projected pixel intensities for the surface points.

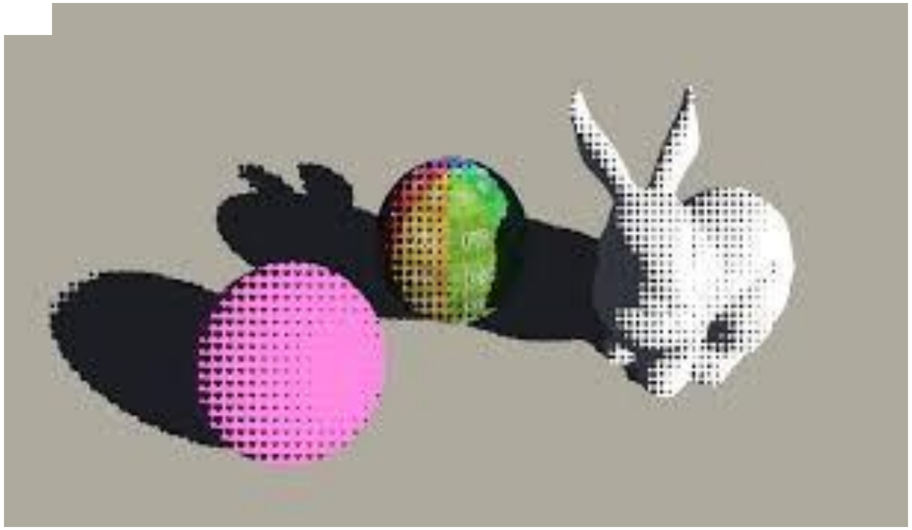


Gouraud Phong

Halftone Shading

- **halftone** is the reprographic technique that simulates continuous-tone imagery through the use of dots, varying either in size or in spacing, thus generating a gradient-like effect.
- "Halftone" can also be used to refer specifically to the image that is produced by this process.
- Where continuous-tone imagery contains an infinite range of colors or greys, the halftone process reduces visual reproductions to an image that is printed with only one color of ink, in dots of differing size (pulse-width modulation) or spacing (frequency modulation) or both.





Hidden Surfaces

- The surface that are blocked or hidden from view must be removed in order of 3D scene.
- The identification and removing of these surfaces is called the hidden surface problem.
- There are many hidden surface algorithm each can be characterized as either an image space method or an object space method.
- One of the most challenging problems in computer graphics is the removal of hidden parts from images of solid objects.
- In the computer generation, no such automatic elimination takes place when objects are projected onto the screen coordinate system.

- Instead, all parts of every object, including many parts that should be invisible are displayed.
- To remove these parts to create a more realistic image, we must apply a hidden line or hidden surface algorithm to set of objects.
- The algorithm operates on different kinds of scene models, generate various forms of output or cater to images of different complexities.
- Types of hidden surface detection algorithms

1. Object space methods
2. Image space methods

- **Object space methods:** In this method, various parts of objects are compared. After comparison visible, invisible or hardly visible surface is determined.

- **Image space methods:** Here positions of various pixels are determined. It is used to locate the visible surface instead of a visible line. Each point is detected for its visibility. If a point is visible, then the pixel is on, otherwise off.

- **Algorithms used for hidden line surface detection**

1. Back Face Removal Algorithm
2. Z-Buffer Algorithm
3. Painter Algorithm
4. Scan Line Algorithm
5. Subdivision Algorithm
6. Floating horizon Algorithm

Back face Removal

- Object surfaces that are oriented away from the viewer are called back faces.
- The back faces of cube are completely blocked by the cube itself and hidden from view.
- Therefore, we can identify and remove these back faces.
- Equation of plane is,

$$Ax+By+Cz+D=0 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

- In object space method, the identification of back faces is based on above equation.
- From above equation, we can say, if a point (x, y, z) satisfies the equation then the point (x, y, z) is lying on the plane but,

$$\text{if } Ax+By+Cz+D<0 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

It means (x,y,z) lies on negative side

$$\text{and if } Ax+By+Cz+D>0 \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

It means (x,y,z) lies on positive side

- If we consider any point (x,y,z) as viewing point, then any plane which satisfies the eq(2) must be a back face.
- After finalizing the back face we have to remove it from the further visibility.

Advantages

- It is a simple and straight forward method.
- It reduces the size of databases, because no need of store all surfaces in the database, only the visible surface is stored.

Z-Buffer Algorithm

- It is also called a **Depth Buffer Algorithm**. Depth buffer algorithm is simplest image space algorithm.
- For each pixel on the display screen, we keep a record of the depth of an object within the pixel that lies closest to the observer.
- In addition to depth, we also record the intensity that should be displayed to show the object.
- Depth buffer is an extension of the frame buffer.
- Depth buffer algorithm requires 2 arrays, intensity and depth each of which is indexed by pixel coordinates (x, y).

Painters Algorithm

- The painters algorithm processes polygons as if they are painted onto the viewer plane, in order of their distance from the viewer.
- It is similar to work of painter.

Fig. a

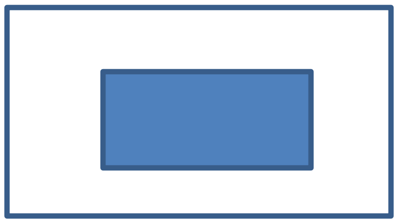


Fig. b

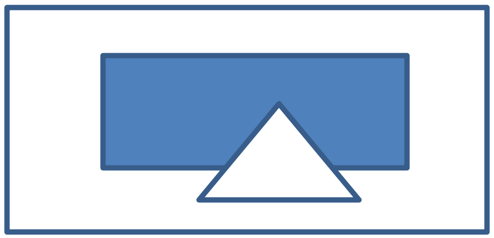


Fig. c