ILLUMINATION AND COLOUR MODELS 4

CHAPTER IN A NUTSHELL

❑ **Illumination** : Illumination is the exposure of an object to the light. Illumination and shading is the last important step in 3D graphics pipeline. An illumination which is also called lighting model or shading model, is used to calculate the intensity of the light that is reflected at a given point on the surface of the object.

Illumination consists of three parts

(1) Ambient reflection

(2) Diffuse reflection

(3) Specular reflection

1. **Ambient Reflection :** Few object surfaces in a scene are not illuminated by direct light sources but they are still available. These light rays are categorized as ambient light. This results from the effect of multiple reflections of light from many surfaces present in the environment.

2. **Diffuse Reflection :** Diffuse reflection is the characteristics of light reflected from a dull, non-shiny surface. Diffuse reflections are constant over-each surface in a scene, independent of the viewing direction.

3. **Specular Refection :** Specular reflection is observed on a shiny surface. Specular reflection is when the reflection is stronger in one viewing direction, in a concentrated region around specular reflection angle.

❑ **RGB Color Model :** The RGB color model is composed of the primary colors red, green and blue. Thus, RGB model is used in most color CRT monitors and color raster graphics.

The RGB colors are considered the "additive primaries" since the color are added together to produce the desired color.

YIQ Color Model : This is the color model used by U.S. commercial color television broadcasting. It is a recording of RGB for transmission efficiency and for downward compatibility for black and white television.

CMY Color Model : The CMY color model stands for cyan, magenta and Yellow which are the complements of red, green and blue respectively. Thus system is used primarily for printing. The CMY color are called the "subtractive primaries" since the color is obtained from, by what is removed from white not added.

HSV Color Model : HSV color model stands for HUV, saturation and value based on the artists. Use selects a spectral color and the amount of white and black that are to be added to obtain different shaded tints and tones.

PREVIOUS YEARS QUESTIONS

PART-A

Q.1 ***What do you mean by illumination? Write its types.***

Ans. An illumination which is also called lighting model or shading model, is used to calculate the intensity of the light that is reflected at a given point on the surface of the object.

Illumination consists of three parts

(1) Ambient reflection

(2) Diffuse reflection

(3) Specular reflection

Q.2 ***Write two differences between CMY and RGB color model.***

Ans.

S.No.	RGB	CMY
1	More color space	Low color space
2	Use less numbers to encode a color	Use more number to encode a color

Q.3 ***What do you mean by diffuse reflection.***

Ans. Diffuse reflection is the characteristics of light reflected from a dull, non-shiny surface.

Q.4 ***Why RGB model is used.***

Ans. The RGB color model is composed of the primary colors red, green and blue. Thus, RGB model is used in most color CRT monitors and color raster graphics.

PART-B

Q.5 ***What are diffused and specular reflection? And write down the illumination model that incorporates both these reflection explain all the variables used in this model?*** ***[R.T.U. 2015]***

OR

Explain the Diffuse reflection and specular reflection ***[R.T.U. 2018]***

OR

Write short note on Specular reflection. ***[R.T.U. 2013]***

Ans. Diffuse Illumination (Reflection) : An object illumination is as important as its surface properties in computing its intensity. The object may be illuminated by light which does not come from any particular source but which comes from all directions. When such illumination is uniform from all directions, the illumination is called **diffuse illumination**. Usually, diffuse illumination is a background light which is reflected from walls, floor and ceiling.

When we assume that going up, down, right and left is of same amount then we can say that the reflections are constant over each surface of the object and they are independent of the viewing direction. Such a reflection is called **diffuse reflection**. In practice, when object is illuminated, some part of light energy is absorbed by the surface of the object while the rest is reflected. The ratio of the light reflected from the surface to the total incoming light to the surface is called **coefficient of reflection** or the **reflectivity**. It is denoted by R. The value of R varies from 0 to 1. It is closer to 1 for white surface and closer to 0 for black surface. This is because white surface reflects nearly all incident light whereas black surface absorbs most of the incident light. Reflection coefficient for gray shades is in between 0 to 1. In case of color object reflection coefficient are various for different color surfaces.

Specular Reflection : When we illuminate a shiny surface such as polished metal with a bright light, we observe highlight or bright spot on the shiny surface. This phenomenon of reflection of incident light in a concentrated region around the specular reflection angle is called **specular reflection**. Due to specular reflection, at the highlight, the surface appears to be not in its original colour, but white, the colour of incident light.

The Fig. shows the specular reflection direction at a point on the illuminated surface. The specular reflection angle equals the angle of the incident light, with the two angles measured on opposite sides of the unit normal surface vector N. As shown in the Fig., R is the unit vector in the direction of ideal specular reflection, L is the unit vector directed toward the point light source and V is the unit vector pointing to the viewer from the surface position.

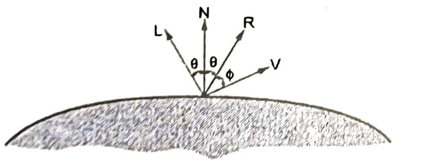

Fig. : Specular reflection

The angle ϕ between vector R and vector V is called viewing angle. For an ideal reflector (perfect mirror), incident light is reflected only in the specular reflection direction. In such case, we can see reflected light only when vector V and R coincide, *i.e.*, $\phi = 0$.

Combined Diffuse and Specular Reflection : For a single point light source, the combined diffuse and specular reflections from any point on the illuminated surface is given as

$$I = I_{diff} + I_{spec}$$

$$= k_a I_a + k_d I_l (N.L) + k_s I_l (N.H)^{ns}$$

For a multiple point light source the above equation can be modified as

$$I = k_a I_a + \sum_{i=1}^{M} I_{l_i} \left[k_d (N.L_i) + k_s (N.H_i)^{ns} \right]$$

where

K_a = ambient-reflection coefficient

I_a = ambient light intensity

K_d = diffuse-reflection coefficient

I_Q = diffuse light intensity

K_s = specular-reflection coefficient

η_s = specular-reflection parameter

Therefore, in case of multiple point light sources the light reflected at any surface point is given by summing the contributions from the individual sources.

Q.6 ***Explain Illumination model.*** ***[R.T.U. 2017]***

Ans. Illumination model : An illumination which is also called lighting model or shading model, is used to calculate the intensity of the light that is reflected at a given point on the surface of the object. This illumination model is further used by rendering process to determine the light intensity of each projected pixel position in a scene.

Creating a virtual reality of a real scene (say a class room) involves:

- Modeling and positioning of several complex objects.
- Determine the visible surface and project the view w.r.t. the viewer,
- Obtain shading using surface normal, surface properties and light sources.
- Obtain shadows from occlusions

Q.7 ***Discuss about the difference between CMY and RGB color?*** ***[R.T.U. 2015]***

Ans. RGB and its subset CMY form the most basic and well-known color model. This model bears closest resemblance to how we perceive color. It also corresponds to the principles of additive and subtractive colors.

Differences between CMY and RGB Color

S.No.	RGB	CMY
1	RGB is based on projecting. Red light plus Green light plus Blue light all projected together create white. Black is encoded as the absence of any color.	CMYK is based on ink. Superimpose Cyan ink plus Magenta ink plus Yellow ink, and we get black, although this format also encodes Black (K) directly. White is encoded by the absence of any color.
2	Prism uses RGB internally. Exporting in RGB will give you results very close to what we see on screen.	Even though it uses one more number to encode a color, the CMYK scheme encodes a smaller "color space" than does RGB.
3	More color space	Low color space
4	Use less numbers to encode a color	Use more number to encode a color
5	It is additive	It is subtractive
6	Mostly used for screen purpose	Mostly used for printing purpose

Q.8 ***Explain how to simulate reflections from surfaces of different roughness using a reflection map.*** ***[R.T.U. Dec. 2013]***

Ans. A basic Reflection map creates the illusion of chrome, glass, or metal by applying a map to the geometry so that the image looks like a reflection on the surface.

An automatic Reflection map does not use mapping coordinates, but instead looks outward from the center of the object and maps what it "sees" onto the surface.

Another way to generate reflections automatically is to assign a Raytrace map to be the reflection map.

A flat-mirror Reflection map is applied to a series of coplanar faces and reflects objects facing it, exactly like a real mirror. The most common use of Reflection maps in a realistic scene is to add just a touch of reflection to an otherwise non-reflective surface. By default, Reflection map strength is 100 percent, as it is for other maps. For many kinds of surfaces, however, reducing the strength gives the most realistic result. A polished table top, for example, primarily shows a wood grain; the reflections are secondary.

Q.9 Write a short note on light sources.

Ans. 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 (Fig. 1) Thus, a surface that is not directly exposed to a light source may still be visible if nearby objects are illuminated. Sometimes, light sources are referred to as light emitting sources; and reflecting surfaces, such as the walls of a room, are termed light reflecting sources. We will use the term light source to mean an object that is emitting radiant energy, such as a light bulb or the sun.

A luminous object, in general, can be both a light source and a light reflector. For example, a plastic globe with a light bulb inside both emits and reflects light from the surface of the globe. Emitted light from the globe may then illuminate other objects in the vicinity.

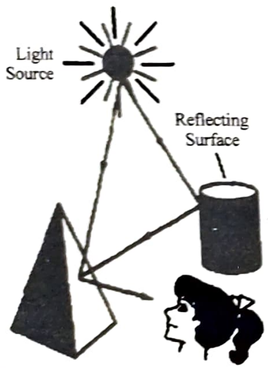

Fig. 1 : Light viewed from an opaque nonluminous surface

The simplest model for a light emitter is a point source. Rays from the source then follow radially diverging paths from the source position, as shown in fig. 2. This light-source model is a reasonable approximation for sources whose dimensions are small compared to the size of objects in the scene. Sources, such as the sun, that are sufficiently far from the scene can be accurately modeled as point sources. A nearby source, such as the long fluorescent light in fig. 3, is more accurately modeled as a distributed light source. In this case, the illumination effects cannot be approximated realistically with a point source, because the area of the source is not small compared to the surfaces in the scene. An accurate model for the distributed source is one that considers the accumulated illumination effects of the points over the surface of the source.

When light is incident on an opaque surface, part of it is reflected and part is absorbed. The amount of incident light reflected by a surface depends on the type of material. Shiny materials reflect more of the incident light, and dull surfaces absorb more of the incident light. Similarly, for an illuminated transparent surface, some of the incident light will be reflected and some will be transmitted through the material.

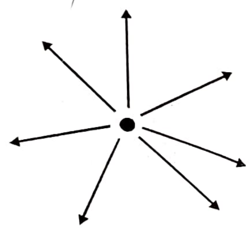

Fig. 2 : Diverging ray path from a point light source

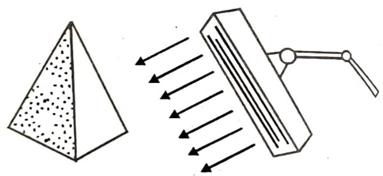

Fig. 3 : An object illuminated with a distributed light source

Surfaces that are rough, or grainy, tend to scatter the reflected light in all directions. This scattered light is called diffuse reflection. A very rough matte surface produces primarily diffuse reflections, so that the surface appears equally bright from all viewing directions. Fig. 4 illustrate diffuse light scattering from a surface. What we call the color of an object is the color of the diffuse reflection of the incident light. A blue object illuminated by a white light source, for example, reflects the blue component of the white light and totally absorbs all other components. If the blue object is viewed under a red light, it appears black since all of the incident light is absorbed.

Fig. 4 : Diffuse reflections from a surface

In addition to diffuse reflection, light sources create highlights or bright spots called specular reflection. This highlighting effect is more pronounced on shiny surfaces than on dull surfaces.

Q.10 What are the standard primaries and the chromaticity diagram.

Ans. Standard Primaries and the Chromaticity Diagram : Since no finite set of color sources can be combined to display all possible colors, three standard primaries were defined in 1931 by the International Commission on Illumination, referred to as the CIE (Commission Internationale Eclairage). The three standard primaries are imaginary colors. They are defined mathematically with positive color-matching functions (Fig. 1) that specify the amount of each primary needed to describe any spectral color.

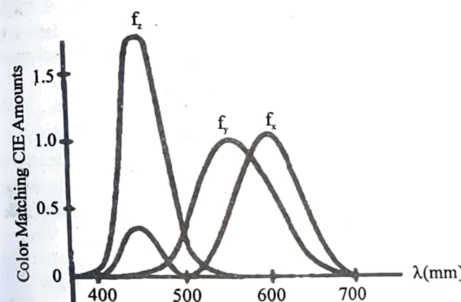

Fig. 1 : Amounts of CIE primaries needed to display spectral colors

This provides an international standard definition for all colors, and the CIE primaries eliminate negative-value color matching and other problem associated with selecting a set of real primaries.

XYZ Color Model : The set of CIE primaries is generally referred to as the XYZ, or (X, Y, Z), color model, where X, Y and Z represent vectors in a three-dimensional, additive color space. Any color C_A, is then expressed as

$$C_A = XX + YY + ZZ \quad \ldots \text{(i)}$$

where X, Y and Z designate the amounts of the standard primaries needed to match C_A.

In discussing color properties, it is convenient to normalize the amounts in Eq. (i) against luminance (X + Y + Z). Normalized amounts are thus calculated as

$$x = \frac{X}{X+Y+Z},$$

$$y = \frac{Y}{X+Y+Z},$$

$$z = \frac{Z}{X+Y+Z} \quad \ldots \text{(ii)}$$

with x + y + z = 1. Thus, any color can be represented with just the x and y amounts. Since we have normalized against luminance, parameters x and y are called the chromaticity values because they depend only on hue and purity. Also, if we specify colors only with x and y values, we cannot obtain the amounts X, Y and Z. Therefore, a complete description of a color is typically given with the three values x, y and Y. The remaining CIE amounts are then calculated as

$$X = \frac{x}{y}Y,$$

$$Z = \frac{z}{y}Y \quad \ldots \text{(iii)}$$

where $z = 1 - x - y$. Using chromaticity coordinates (x, y), we can represent all colors on a two-dimensional diagram.

CIE Chromaticity Diagram : When we plot the normalized amounts x and y for colors in the visible spectrum, we obtain the tongue-shaped curve shown in fig. 2.

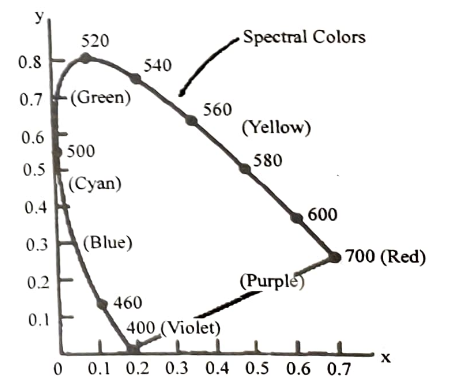

Fig. 2 : CIE chromaticity diagram. Spectral color position along the curve are labeled in wavelength units (nm)

This curve is called the CIE chromaticity diagram. 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. The line joining the red and violet spectral points, called the purple line, is not part of the spectrum. Interior points represent all possible visible color combinations. Point C in the diagram corresponds to the white-light position. Actually, this point is plotted for a white-light source known as illuminant C, which is used as a standard approximation for "average" daylight.

Luminance values are not available in the chromaticity diagram because of normalization. Colors with different luminance but the same chromaticity map to the same point. The chromaticity diagram is useful for the following:

- Comparing color gamuts for different sets of primaries.
- Identifying complementary colors.
- Determining dominant wavelength and purity of a given color.

Q.11 ***What is intuitive color concepts. Explain HLS color model.***

Ans. Intuitive Color Concepts : An artist creates a color painting by mixing color pigments with white and black pigments to form the various shades, tints, and tones in the scene. Starting with the pigment for a "pure color" (or "pure hue"), the artist adds a black pigment to produce different shades of that color. The more black pigment, the darker the shade. Similarly, different tints of the color are obtained by adding a white pigment to the original color, making it lighter as more white is added. Tones of the color are produced by adding both black and white pigments.

To many, these color concepts are more intuitive than describing a color as a set of three numbers that give the relative proportions of the primary colors. It is generally much easier to think of making, a color lighter by adding white and making a color darker by adding black. Therefore, graphics packages providing color palettes to a often employ two or more color models. One model provides an intuitive color interface for the user, and others describe the color components for the output devices.

HLS Color Model : Another model based on intuitive color parameters is the HLS system used by Tektronix. This model has the double-cone representation shown in fig. The three color parameters in this model are called hue (H), lightness (L), and saturation (S).

Hue has the same meaning as in the HSV model. It specifies an angle about the vertical axis that locates a chosen hue. In this model, H = 0° corresponds to blue. The remaining colors are specified around the perimeter of the cone in the same order as in the HSV model. Magenta is at 60°, red is at 120°, and cyan is located at H = 180°. Again, complementary colors are 180° apart on the double cone.

The vertical axis in this model is called lightness, L. At L = 0, we have black, and white is at L = 1. Gray scale is along the L axis, and the "pure hues" lie on the L = 0.5 plane.

Saturation parameter S again specifies relative purity of a color. This parameter varies from 0 to 1, and pure hues are those for which S = 1 and L = 0.5. As S decreases, the hues are said to be less pure. At S = 0, we have the gray scale.

As in the HSV model, the HLS system allows a user to think in terms of making a selected hue darker or lighter. A hue is selected with hue angle H, and the desired shade, tint, or tone is obtained by adjusting L and S. Colors are made lighter by increasing L and made darker by decreasing L. When S is decreased, the colors move toward gray.

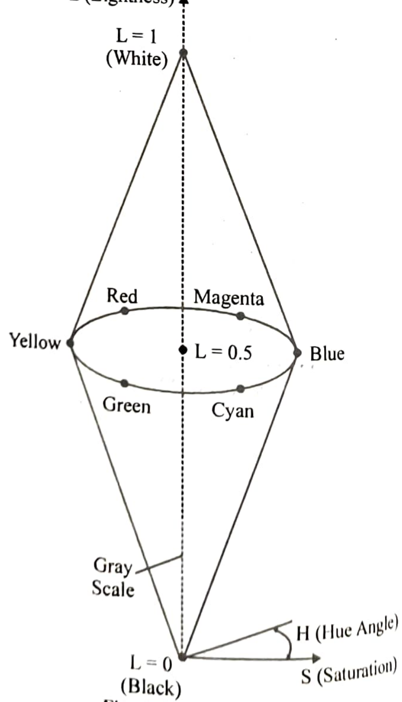

Fig. : The HLS double cone

Q.12 ***Explain the concept of color selection.***

Ans. Color Selection : A graphics package can provide color capabilities in a way that aids us in making color selections. Various combinations of colors can be selected using sliders and color wheels, and the system can also be designed to aid in the selection of harmonizing colors. In addition, the designer of a package can follow some basic color rules when designing the color displays that are to be presented to a user.

One method for obtaining a set of coordinating colors is to generate the set from some subspace of a color model. If colors are selected at regular intervals along any straight line within the RGB or CMY cube, for example, we can expect to obtain a set of well-matched colors. Randomly selected hues can be expected to produce harsh and clashing color combinations. Another consideration in the selection of color combinations is that different colors are perceived at different depths. This occurs because our eyes focus on colors according to their frequency. Blues, in particular, tend to recede. Displaying a blue pattern next to a red pattern can cause eye fatigue, because we continually need to refocus when our attention is switched from one area to the other. Thus problem can be reduced by separating these colors or by using colors from one-half or less of the color hexagon in the HSV model. With this technique, a display contains either blues and greens or reds and yellows.

As a general rule, the use of a smaller number of colors produces a more pleasing display than a large number of colors, and tints and shades blend better than pure hues. For a background, gray or the complement of one of the foreground colors in usually best.

PART-C

Q.13 ***Discuss following color models :***

(i) RGB
(ii) YIQ
(iii) CMY *[R.T.U. 2016]*

OR

Explain color model RGB. Compare it with HSV. *[R.T.U. 2017]*

OR

What is HSV color model? *[R.T.U. 2016]*

OR

Discuss about half-toning. Explain in brief about RGB, CMY and HSQ color models.
[Note : Read HSQ as HSV.]
[R.T.U. 2018, 2009; R.U. 2007, 2004]

OR

Explain in brief about RGB, CMY and HSV color models. *[R.T.U. Dec. 2013]*

OR

Explain RGB and CMY color models. *[R.U. 2010]*

Ans. Half Toning : Continuous tone photographs are reproduced for publication in newspapers, magazines and books with a printing process called half toning and the reproduced pictures are called half tones. Half tone reproductions are approximated using rectangular pixel regions called half tone patterns or pixel patterns.

(i) RGB Color Model : Theory of vision (according to which visual pigments have a peak sensitivity at wavelength of red, blue and green colors) is the basis for displaying the color output on a video monitor using three primaries red, green and blue refined to as the RGB color model.

This model can be represented with the unit cube defined on R, G and B axis. The origin represents black and the vertex with coordinates (1, 1, 1) is white. Vertices of the cube on the axis represents the primary colors and the remaining vertices represent the complementary color for each of the primary colors. RGB color scheme is an additive model.

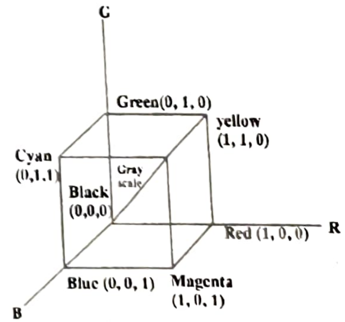

Fig.

Intensities of primary colors are added to produce other colors. Each color point within the bounds of the cube can be represented as the triple (R, G, B), where values for R, G and B are assigned in the range from 0 to 1. Thus a color C_λ is expressed in RGB components as :

$$C_\lambda = RR + GG + BB.$$

The magenta vertex is obtained by adding red, blue to produce the triple (1, 0, 1) and white at (1, 1, 1) is the sum of the red, green and blue vertices.

(ii) YIQ Color Model : The national Television System Committee (NTSC) color model for forming the composite video signal is the YIQ model, which is based on concepts in the CIE XYZ model.

In the YIQ color model, parameter Y is the same as in the XYZ model. Luminance (brightness) information is contained in the y parameter, while chromaticity information (hue and parity) incorporated into the I and Q parameters. A combination of red, green and blue intensities are chosen for the y parameter to yield the standard luminosity curve. Since y contains the luminance information, black and white television monitors use only the y signal. The largest bandwidth in the NTSC video signal (about 4 MHz) is assigned to the y information. Parameter I contains orange-cyan hue information that provides the flesh tone shading, and occupies a bandwidth of approximately 1.5 MHz. parameter Q carries green-magneta hue information in a bandwidth of about 0.6 MHz.

The conversion from RGB values to YIQ values is accomplished with the transformation.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

(iii) CMY Color Model : A color model define with the primary colors cyan, magenta and yellow (CMY) is useful for describing color output to hard copy devices unlike video monitors, which produce a color pattern by combining light from the screen phosphors, the colors are seen by reflected light, a subtractive process. As noted, cyan can be formed by adding green and blue light.

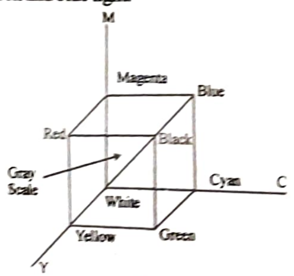

Fig.

Therefore, when white light is reflected from cyan colored ink, the reflected light must have no red components. That is, red light is absorbed, or subtracted by the ink. Similarly, magenta ink subtracts the green component from incident light, and yellow subtracts the blue component.

In the CMY model, point (1, 1, 1) represents black because components of the incident light are subtracted. The origin represents the white light. Equal amounts of each of the primary colors produce group, along the main diagonal of the cube.

A combination of cyan and magenta ink produces blue light, because the red and green components of the incident light are absorbed. Other color combinations are obtained by a similar subtractive process.

HSV Color Model : Instead of a set of color primaries, the HSV model uses color descriptions that have a more intutive appeal to a user.

To give a color specification, a user selects a spectral color and the amounts of white and black that are to be added to obtain different shades, tints and tones. Color parameters in this model are hue (H), saturation (S) and value (V).

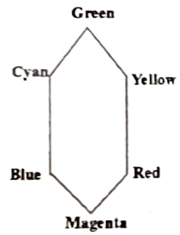

Fig.

The three dimensional representation of the HSV model is derived from the RGB cube. If we imagine viewing the cube along the diagonal from the white vertex to the origin (black), we see an outline if the cube that has the hexagon shape. The boundary of the hexcone represents the various hus, and it is used as the top of the HSV hexcone. In the hexcone saturation is measured along a horizontal axis, and value is along a vertical axis through the centre of the hexcone.

Q.14 ***What are the various aspects of illumination of objects?*** [R.T.U. 2016]

OR

Explain following terms:

(i) Diffuse reflection

(ii) Specular reflection [R.T.U. 2017]

Ans. Illumination of Objects : An illumination which is also called lighting model or shading model, is used to calculate the intensity of the light that is reflected at a given point on the surface of the object. This illumination model is further used by rendering process to determine the light intensity of each projected pixel position in a scene.

Creating a virtual reality of a real scene (say a class room) involves :

- Modeling and positioning of several complex objects.
- Determine the visible surface and project the view with respect to the viewer.
- Obtain shading using surface normal, surface properties and light sources.
- Obtain shadows from occlusions.
- Illumination consists of three parts :
- Ambient reflection
- Diffuse reflection
- Specular reflection

Thus three types of reflections which occur due to interaction of light and surface, is needed to be implemented by ray tracing techniques and other models, in order to attain realism.

1. Ambient Reflection : Few object surfaces in a scene are not illuminated by direct light sources but they are still visible. This is due to nearby illuminating objects (shiny objects) which reflect the light rays. These light rays in the environment is categorized as ambient light. This is a case of diffuse, non-directional source of light. This results from the effect of multiple reflections of light from many surfaces present in the environment.

Ambient light is assumed to impinge equally on all surfaces from all directions. Thus we can write the illumination equation as :

$$I = I_a K_a$$

where, I_a is the intensity of ambient light assumed to be constant for all objects and K_a is the ambient reflection coefficient ($0 \le K_a \le 1$), property of the surface material.

Though reflected light is constant for each surface, which is independent of the viewing direction and orientation of the surface, but it definitely depends on optical properties of the surface, *i.e.* how much a surface reflects and absorbs the light rays.

2. Diffuse Reflection : Diffuse reflection is characteristic of light reflected from a dull, non shiny surface. Diffuse reflections are constant over each surfaced in a scene, independent of the viewing direction. The object's brightness varies from one place to another depending on the direction of the light source (and also on the distance so some extent). Diffuse reflection models the light reflecting properties of matt surface, *i.e.* the surface that are rough or grainy which tend to scatter the reflected light in all directions. This scattered light is called diffuse reflection.

We are assuming here that diffuse reflection from the surface are scattered with equal intensity in all directions independent of the viewing direction. Such surfaces are ideal diffuse reflectors or Lambertian reflectors. Lamber's cosine law states that in diffuse reflection, intensity of reflected light is proportional to cos θ.

i.e. $I \propto \cos\theta$

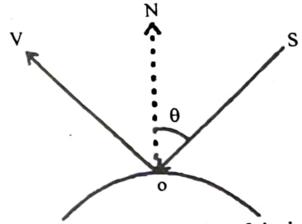

Fig. 1 : Diffuse reflection independent of viewing direction. Angle φ is ignored

Thus, diffuse illumination equation is :

$$I = I_d K_d \cos(\theta)$$

where, I_d is the point light source's intensity and, K_d ($0 \le K_d \le 1$) is material's diffuse reflection coefficient, also, $0 \le \theta \le 90°$

Thus the amount of illumination depends on cos θ. As the angle between the surface normal and light source increases, illumination decreases at the point.

Thus when θ = 90° we have least illumination.

The above illumination equation can be rewritten as :

$$I = I_d K_d(\bar{N}.\bar{S})$$

where $\bar{N}$ and $\bar{S}$ are scalar quantities

So $\bar{N}.\bar{S} = \cos\theta$ (dot product of $\bar{N}$ and $\bar{S}$)

Unless you are in a perfect dark room, a more realistic illumination equation is :

$$I = I_a K_a + I_d K_d(\bar{N}\,\bar{S})$$

This is the total diffuse reflection equation for illumination.

$K_d = 1$ for highly reflective surface reflection whole light.

$K_d = 0$ for surfaces that absorb light completely.

3. Specular Reflection and the Phong Model : Specular reflection is observed on a shiny surface. Specular reflection is when the reflection is stronger in one viewing direction, in a concentrated region around specular reflection angle, *i.e.*, there is a bright spot. Fig. 2 observes the specular reflection.

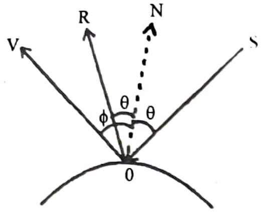

Fig. 2

R is the reflection vector. Angle of incidence equals the angle of specular reflection.

Shiny surface reflects light unequally in different direction. For an ideal reflector, specular reflection is visible only when V (Viewer direction) coincides with R. This is the case of perfect reflector example of which is mirror. For other real objects, specular reflection can be seen also when V and R don't coincide. This is the case of imperfect, non mirror type reflector, example is shiny plastics, gold and silver coated metal surface.

Intensity is the maximum along R, which decreases as α increases. α is the angle between reflection vector R and viewer direction V as shown in fig. 3.

Thus α is the viewing angle relative to R.

If α = 0, viewer will see light of more intensity.

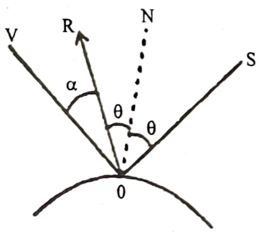

Fig. 3

The local illumination model generally used is :

illumination = Ambient + Diffuse + Specular

It is also called phong specular reflection model. Phong observed that for very shiny surface the specular highlight was small and the intensity fell off rapidly, while for duller surfaces it was larger and fell off more slowly. So phong decided to let the reflected intensity be a function of $(\cos\alpha)^n$, where 'n' is specular reflection parameter dependent on the type of surface. $0 \le a \le 90°$ and n > = 200 for shiny surface and n is small for dull surface.

For a perfect reflector (say mirror) n equals infinity and for a piece of card board n equals 0 or 1.

Thus, the illumination equation for phong specular reflection is :

$$I = I_s K_s \cos^n \alpha$$

where I_s is the intensity of light source

K_s is specular reflection coefficient.

Now, the total intensity when all ambient diffuse specular reflection occurs is :

$$I = I_a K_a + I_d K_d \cos\theta + I_s K_s \cos^n \alpha$$

since α is the angle between vectors V and R which are scalar vector, so,

$$\cos^n \alpha = (\vec{V} . \vec{R})^n$$

here, $\vec{R}$ is the unit vector in specular reflection direction and $\vec{V}$ is the unit vector in viewer direction.

Q.15 *Write a routine to convert RGB color model to HSV color model.* *[R.T.U. 2012]*

Ans. Conversion Between HSV and RGB Models : If HSV color parameters are made available to a user of a graphics package, these parameters are transformed to the RGB settings needed for the color monitor. To determine the operations needed in this transformation, we first consider how the HSV hexcone can be derived from the RGB cube. The diagonal of this cube from black (the origin) to white corresponds to the V axis of the hexcone. Also, each subcube of the RGB cube corresponds to a hexagonal cross-sectional area of the hexcone. At any cross section, all sides of the hexagon and all radial lines from the V axis to any vertex have the value V. For any set of RGB values, V is equal to the maximum value in this set. The HSV point corresponding to the set of RGB values lies on the hexagonal cross section at value V. Parameter S is then determined as the relative distance of this point from the V axis. Parameter H is determined by calculating the relative position of the point within each sextant of the hexagon. An algorithm for mapping any set of RGB values into the corresponding HSV values is given in the following procedure:

```
#include <math.h>
/* Input: h, s, v in range [0..1]
   Outputs; r, g, b in range [0..1] */
void hsvToRgb (float h, float s, float v, float * r, float
* g, float * b)
{ int i;
  float aa, bb, cc, f;
  if (s== 0) /* Grayscale */
```



```
    *r = *g = *b = v;
  else {
    if (h ==1.0) h = 0;
    h * = 6.0;
    i = ffloor (h) ;
    f = h – i;
    aa = v * (1– s);
    bb = v * (1– (s * f));
    cc = v * (1– (s * (1– f)));
    switch (i) {
    case 0: *r = v;  *g = cc; *b = aa; break;
    case 1: *r = bb; *g = v;  *b = aa; break;
    case 2: *r = aa; *g = v;  *b = cc; break;
    case 3: *r = aa; *g = bb; *b = v; break;
    case 4: *r = cc; *g = aa; *b = v; break;
    case 5: *r = v; *g = aa; *b = bb; break;
    }
  } }
```

We obtain the transformation from HSV parameters to RGB parameters by determining the inverse of the equations in *rgbtohsv* procedure.

RGB to HSV Algorithm

```
#include <math.h>
#define MIN(a, b) (a < b? a : b)
#define MAX(a, b) (a > b? a : b)
#define No_H ∪ E – 1
Void rgb to HSv (Float r, float g, float b, float *h,
float *s, float *v)
{
 float max = MAX (r, MAX (g, b)),
 Min = MIN(r, MIN (g, b));
 float delta = Max – Min;
 if (Max ! = 0.0)
 *S = delta/max;
 else
 *S = 0.0;
 if (*S = = 0.0) *h = No_H ∪ E;
 else {
 if (r = = max)
 *h = (g – b)/delta;
 else if (g = = max)
 *h = 2 + (b – r)/delta;
 else if (b = = max)
 *h = 4  (r – g)/delta;
 *h * = 60.0;
 if (*h < 0) *h + = 360.0;
 *h/ = 360.0;
 }
}
```

Q.16 *Explain dithering techniques in detail.*

Ans. Dithering Techniques : The term dithering is used in various contexts. Primarily, it refers to techniques for approximating halftones without reducing resolution, as pixel-grid patterns do. But the term is also applied to halftone-approximations methods using pixel grids, and sometimes it is used to refer to color halftone approximations only.

Random values added to pixel intensities to break up contours are often referred to as dither noise. Various algorithms have been used to generate the random distributions. The effect is to add noise over an entire picture, which tends to soften intensity boundaries.

Ordered-dither methods generate intensity variations with a one-to-one mapping of points in a scene to the display pixels. To obtain n^2 intensity levels, we set up an n by n dither matrix D_n, whose elements are distinct positive integers in the range 0 to $n^2 - 1$. For example, we can generate four intensity levels with

$$D_2 = \begin{bmatrix} 3 & 1 \\ 0 & 2 \end{bmatrix} \quad \ldots \text{(i)}$$

and we can generate nine intensity levels with

$$D_3 = \begin{bmatrix} 7 & 2 & 6 \\ 4 & 0 & 1 \\ 3 & 8 & 5 \end{bmatrix} \quad \ldots \text{(ii)}$$

The matrix elements for D_2 and D_3 are in the same order as the pixel mask for setting up 2 by 2 and 3 by 3 pixel grids, respectively. For a bilevel system, we then determine display intensity values by comparing input intensities to the matrix elements. Each input intensity is first scaled to the range $0 \le 1 \le n^2$. If the intensity I is to be applied to screen position (x, y), we calculate row and column numbers for the dither matrix as

$$i = (x \bmod n) + 1,\ j = (y \bmod n) + 1 \quad \ldots \text{(iii)}$$

If $I > D_n(i,j)$, we turn on the pixel at position (x, y). Otherwise, the pixel is not turned on.

Elements of the dither matrix are assigned in accordance with the guidelines discussed for pixel grids. That is, we want to minimize added visual effect in a displayed scene. Order dither produces constant-intensity areas identical to those generated with pixel-grid patterns when the values of the matrix elements correspond to the grid mask. Variations from the pixel-grid displays occur at boundaries of the intensity levels.

Typically, the number of intensity levels is taken to be a multiple of 2. Higher-order dither matrices are then obtained from lower-order matrices with the recurrence relation:

$$D_n = \begin{bmatrix} 4D_{n/2} + D_2(1,1)U_{n/2} & 4D_{n/2} + D_2(1,2)U_{n/2} \\ 4D_{n/2} + D_2(2,1)U_{n/2} & 4D_{n/2} + D_2(2,2)U_{n/2} \end{bmatrix} \quad \text{... (iv)}$$

Assuming $n \geq 4$. Parameter $U_{n/2}$ is the "unity" matrix (all elements are 1). As an example, if D_2 is specified as in Eq. (i), then recurrence relation (iv) yields.

$$D_4 = \begin{bmatrix} 15 & 7 & 13 & 5 \\ 3 & 11 & 1 & 9 \\ 12 & 4 & 14 & 6 \\ 0 & 8 & 2 & 10 \end{bmatrix} \quad \text{... (v)}$$

Another method for mapping a picture with m by n points to a display area with m by n pixels is error diffusion. Here, the error between an input intensity value and the displayed pixel intensity level at a given position is dispersed, or diffused, to pixel positions to the right and below the current pixel position. Starting with a matrix M of intensity values obtained by scanning a photograph, we want to construct an array I of pixel intensity values for an area of the screen. We do this by first scanning across the rows of M, from left to right, top to bottom, and determining the nearest available pixel-intensity level for each element of M. Then the error between the value stored in matrix M and the displayed intensity level at each pixel position is distributed to neighboring elements in M, using the following simplified algorithm :

for (i = 0; i<m; i++)
for (j=0; j<n; j++) |
I_{ij}; = I_k;
err = $M_{ij} - I_{ij}$;
M_{ij+1} : = M_{ij+1} + α err ;
$M_{i+1, j-1}$; = M_{i+1}
$M_{i+1, j-1}$: = $M_{i+1, j-1}$ + β.err
$M_{i+1, j}$: = $M_{i+1, j}$ + γ.err
$M_{i+1, j+1}$: = $M_{i+1, j+1}$ + δ.err

Q.17 *Write detailed note on various properties of light.*

Ans. Properties of Light : What we perceive as "light", or different colors, is a narrow frequency band within the electromagnetic spectrum. A few of the other frequency bands within this spectrum are called radio waves, microwaves, infrared waves, and X-rays. Figure 1 shows the approximate frequency ranges for some of the electromagnetic bands.

Each frequency value within the visible band corresponds to a distinct color. At the low-frequency end is a red color (4.3×10^{14} hertz), and the highest frequency we can see is a violet color (7.5×10^{14} hertz). Spectral colors range from the reds through orange and yellow at the low-frequency end to greens, blues and violet at the high end.

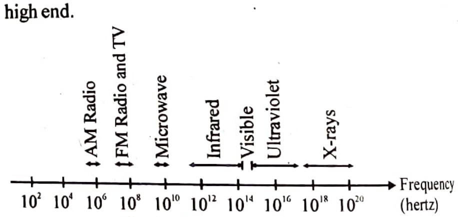

Fig. 1 : Electromagnetic spectrum

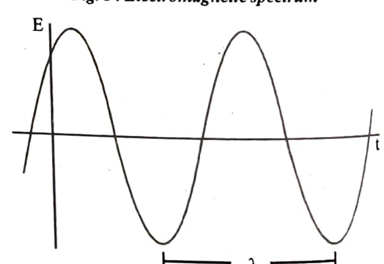

Fig. 2 : Time variations for one electric frequency component of a plane polarized electromagnetic wave

Since light is an electromagnetic wave, we can describe the various colors in terms of either the frequency f or the wavelength λ of the wave. In fig. 2, we illustrate the oscillations present in a monochromatic electromagnetic wave, polarized so that the electric oscillations are in one plane. The wavelength and frequency of the monochromatic wave are inversely

proportional to each other, with the proportionality constant as the speed of light C :

$$C = \lambda f \quad \text{... (i)}$$

Frequency is constant for all materials, but the speed of light and the wavelength are material-dependent. In a vacuum, $C = 3 \times 10^{10}$ cm/sec. Light wavelength are very small, so length units for designating spectral colors are usually either angstroms ($1 Å = 10^{-8}$ cm) or nanometers (1 nm $= 10^{-7}$ cm). An equivalent term for nanometer is millimicron. Light at the red end of the spectrum has wavelength of approximately 700 nanometers (nm), and the wavelength of the violet light at the other end of the spectrum is about 400 nm. Since wavelength units are somewhat more convenient to deal with than frequency units, spectral colors are typically specified in terms of wavelength.

A light source such as the sun or a light bulb emits all frequencies within the visible range to produce white light. When white light is incident upon an object, some frequencies are reflected and some are absorbed by the object. The combination of frequencies present in the reflected light determines what we perceive as the color of the object. If low frequencies are predominant in the reflected light, the object is described as red. In this case, we say the perceived light has a dominant frequency (or dominant wavelength) at the red end of the spectrum. The dominant frequency is also called the hue, or simply the color, of the light.

Other properties besides frequency are needed to describe the various characteristics of light. When we view a source of light, our eyes respond to the color (or dominant frequency) and two other basic sensations. One of these we call the brightness, which is the perceived intensity of the light. Intensity is the radiant energy emitted per unit solid angle, and per unit projected area of the source. Radiant energy is related to the luminance of the source.

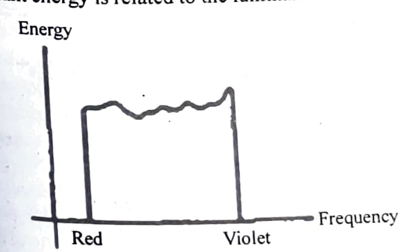

Fig. 3 : Energy distribution of a weight-light source

The second perceived characteristic is the purity, or saturation, of the light. Purity describes how washed out or how "pure" the color of the light appears. Pastels and pale colors are described as less pure. These three characteristics, dominant frequency, brightness, and purity, are commonly used to describe the different properties we perceive in a source of light. The term chromaticity is used to refer collectively to the two properties describing color characteristics purity and dominant frequency.

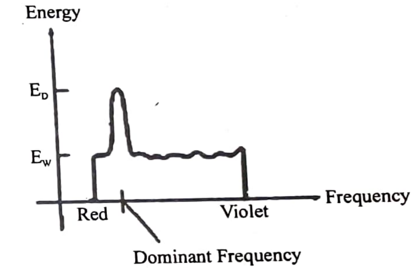

Fig. 4 : Energy distribution of a light source with a dominant frequency near the red end of the frequency range

Energy emitted by a white-light source has a distribution over the visible frequencies as shown in fig. 3. Each frequency component within the range from red to violet contributes more or less equally to the total energy, and the color of the source is described as white. When a dominant frequency is present, the energy distribution for the source takes a form such as that in fig. 4. We have would now describe the light as having the color corresponding to the dominant frequency. The energy density of the dominant light component is labeled as E_D in this figure, and the contributions from the other frequencies produce white light of energy density E_w. We can calculate the brightness of the source as the area under the curve, which gives the total energy density emitted. Purity depends on the difference between E_D and E_w. The larger the energy E_D of the dominant frequency compared to the white-light component E_w, the more pure the light. We have a purity of 100 percent when $E_w = 0$ and a purity of 0 percent when $E_w = E_D$.

When we view light that has been formed by a combination of two or more sources, we see a resultant light with characteristics determined by the original sources. Two different-color light sources with suitably chosen intensities can be used to produce a range of other 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, blue and yellow. With a judicious choice of two or more starting colors, we can form a wide range of other colors. Typically, color models that are used to describe combinations of light in terms of dominant frequency (hue) use three colors to obtain a reasonably wide range of colors, called the color gamut for that model. The two or three colors used to produce other colors in such a color model are referred to as primary colors.

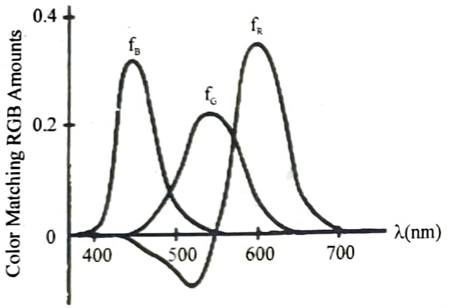

Fig. 5 : Amount of RGB primaries needed to display special colors

No finite set of real primary colors can be combined to produce all possible visible colors. Nevertheless, three primaries are sufficient for most purposes, and colors not in the color gamut for a specified set of primaries can still be described by extended methods. If a certain color cannot be produced by combining the three primaries, we can mix one or two of the primaries with that color to obtain a match with the combination of remaining primaries. In this extended sense, a set of primary colors can be considered to describe all colors. Fig. 5 shows the amounts of red, green, and blue needed to produce any spectral color. The curves plotted in fig. 5, called color-matching functions, were obtained by averaging the judgments of a large number of observers. Colors in the vicinity of 500 nm can only be matched by "subtracting" an amount of red light from a combination of blue and green lights. This means that a color around 500 nm is described only combining that color with an amount of red light to produce the blue-green combination specified in the diagram. Thus, an RGB color monitor cannot display colors in the neighborhood of 500 nm.

□□□

Animation and Computer Graphics Realism 5

Chapter in a Nutshell

- **Ray Tracing Methods :** Ray tracing is an extension of this basic idea. Instead of merely looking for the visible surface for each pixel, We continue to bounce the ray around the scene collecting intensity contributions. Th provides a simple and powerful rendering technique f obtaining global reflection and transmission effects.

Previous Years Questions

Part-A

Q.1 ***What is computer graphics realism?***

Ans. Computer Graphics Realism : The creation of realistic picture in computer graphics is known as realism. It is important in fields such as simulation, design, entertainments, advertising, research, education, command, and control.

Q.2 ***How realistic pictures are created in computer graphics?***

Ans. To create a realistic picture, it must be process the scene or picture through viewing coordinate transformations and projection that transform 3D viewing coordinates onto 2D device coordinates.

Q.3 ***What is Fractals?***

Ans. Fractal : A fractal is an image or a geometric object with self-similar, infinite properties produced by recursive or iterative algorithms.

Q.4 ***What is Koch Curve?***

Ans. Koch Curve : The Koch curve is a curve that generated by a simple geometric procedure which can iterated an infinite number of times by dividing a straig line segment into three equal parts and substituting th intermediate part with two segment of the same length

Q.5 ***What is turtle graphics program?***

Ans. Turtle Graphics Program : The turtle program a Robert that can move in two dimensions and it has pencil for drawing. The turtle is defined by the followin parameters :

Position of the turtle(x, y)

Heading of the turtle( ) the angle from the x-axi

Part-B

Q.6 ***Write short note on simple recursive ray tracir without antialiasing.*** *[R.T.U. Dec. 201*