# Computer Graphics & Multimedia (5CS4-04)

## Computer Science and Engineering Department

## Vision of the Department

To become renowned Centre of excellence in computer science and engineering and make competent engineers & professionals with high ethical values prepared for lifelong learning.

## Mission of the Department

- To impart outcome based education for emerging technologies in the field of computer science and engineering.
- To provide opportunities for interaction between academia and industry.
- To provide platform for lifelong learning by accepting the change in technologies.
- To develop aptitude of fulfilling social responsibilities.

## Program Outcomes (PO):

- **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- **Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

- **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

- **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

- **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

- **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

- **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## Program Educational Objectives (PEO):

**PEO1**: To provide students with the fundamentals of Engineering Sciences with more emphasis in computer science and engineering by way of analyzing and exploiting engineering challenges.

**PEO2:** To train students with good scientific and engineering knowledge so as to comprehend, analyze, design, and create novel products and solutions for the real life problems.

**PEO3**: To inculcate professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, entrepreneurial thinking and an ability to relate engineering issues with social issues.

**PEO4:** To provide students with an academic environment aware of excellence,leadership, written ethical codes and guidelines, and the self-motivated life-long learning needed for a successful professional career.

**PEO5**: To prepare students to excel in Industry and Higher education by educating Students along with High moral values and Knowledge.

### Program Specific Outcome (PSO):

**PSO:** Ability to interpret and analyze network specific and cyber security issues, automation in real word environment.
**PSO2:** Ability to Design and Develop Mobile and Web-based applications under realistic constraints.

**Course Outcome (CO):**

**CO1**: Implement geometric images using graphical input techniques

**CO2**: Design and develop images with the help of 2D & 3D transformations.

**CO3**: Identify visible surfaces for generation of realistic graphics display and curves representation.

**CO4**: Analyse multimedia and animation techniques.

**CO-PO Mapping**

**Computer Graphics & Multimedia Techniques 5CS4-04**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 : Implement geometric images using graphical input techniques | 3 | 2 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 3 |
| CO2: Design and develop images with the help of 2D & 3D transformations. | 3 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 3 |
| CO3: Identify visible surfaces for generation of realistic graphics display and curves representation. | 3 | 3 | 3 | 3 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 3 |
| CO4: Analyse multimedia and animation techniques. | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 2 | 2 | 3 |

**CO-PSO Mapping**

| CO's | PSO1 | PSO2 |
|---|---|---|
| CO1: Implement geometric images using graphical input techniques | 2 | 2 |
| CO2: Design and develop images with the help of 2D & 3D transformations. | 2 | 2 |
| CO3: Identify visible surfaces for generation of realistic graphics display and curves representation. | 2 | 2 |
| CO4: Analyse multimedia and animation techniques. | 2 | 2 |

# RAJASTHAN TECHNICAL UNIVERSITY, KOTA

**Syllabus**

**III Year-V Semester: B.Tech. Computer Science and Engineering**

## 5CS4-04: Computer Graphics & Multimedia

**Credit: 3** **Max. Marks: 150(IA:30, ETE:120)**
**3L+0T+0P** **End Term Exam: 3 Hours**

| SN | Contents | Hours |
|---|---|---|
| 1 | **Introduction:** Objective, scope and outcome of the course. | 01 |
| 2 | **Basic of Computer Graphics:**Basic of Computer Graphics, Applications of computer graphics, Display devices, Random and Raster scan systems, Graphics input devices, Graphics software and standards | 06 |
| 3 | **Graphics Primitives:**Points, lines, circles and ellipses as primitives, scan conversion algorithms for primitives, Fill area primitives including scan-line polygon filling, inside-outside test, boundary and flood-fill, character generation, line attributes, area-fill attributes, character attributers. Aliasing, and introduction to Anti Aliasing (No anti aliasing algorithm). | 07 |
| 4 | **Two Dimensional Graphics:**Transformations (translation, rotation, scaling), matrix representation, homogeneous coordinates, composite transformations, reflection and shearing, viewing pipeline and coordinates system, window-to-viewport transformation, clipping including point clipping, line clipping (cohen-sutherland, liang- bersky, NLN), polygon clipping | 08 |
| 5 | **Three Dimensional Graphics:**3D display methods, polygon surfaces, tables, equations, meshes, curved lies and surfaces, quadric surfaces, spline representation, cubic spline interpolation methods, Bazier curves and surfaces, B-spline curves and surfaces.3D scaling, rotation and translation, composite transformation, viewing pipeline and coordinates, parallel and perspective transformation, view volume and general (parallel and perspective) projection transformations. | 08 |
| 6 | **Illumination and Colour Models:**Light sources – basic illumination models – halftone patterns and dithering techniques; Properties of light – Standard primaries and chromaticity diagram; Intuitive colour concepts – RGB colour model – YIQ colour model – CMY colour model – HSV colour model – HLS colour model; Colour selection. | 06 |
| 7 | **Animations &Realism:**Design of Animation sequences – animation function – raster animation – key frame systems – motion specification – morphing – tweening.<br><br>**ComputerGraphics Realism:** Tiling the plane – Recursively defined curves – Koch curves – C curves – Dragons – space filling curves – fractals – Grammar based models – fractals – turtle graphics – ray tracing. | 06 |
| | **Total** | 42 |

Lecture Plan of Computer Graphics & Multimedia Techniques ( CGMT)
5CS4-04

| **Unit No./ Total lec. Req.** | **Topics** | **Lect. Req.** |
|---|---|---|
| Unit-1(1) | Introduction: Objective, scope and outcome of the course. | 1 |
| Unit-2 (6) | Basic of Computer Graphics | 1 |
| | Applications of computer graphic, Display devices | 2 |
| | Random and Raster scan systems | 1 |
| | Graphics input devices, Graphics software and standards | 2 |
| Unit-3(7) | Points,lines,circles and ellipses as primitives, scan conversion algorithms for primitives | 3 |
| | Fill area primitives including scan- line polygon filling, inside-outside test, boundary and flood-fill | 2 |
| | character generation, line attributes, area-fill attributes, character attributers. Aliasing, and introduction to Anti Aliasing (No anti aliasing algorithm) | 2 |
| Unit-4(8)- | Transformations (translation, rotation, scaling), matrix representation | 1 |
| | homogeneous coordinates, composite transformations, reflection and shearing | 1 |
| | viewing pipeline and coordinates system | 2 |
| | window-to-viewport transformation, clipping including point clipping | 2 |
| | line clipping (cohen-sutherland,liang- bersky, NLN), polygon clipping | 2 |
| Unit-5(8) | 3D display methods, polygon surfaces, tables, equations, meshes, curved lies and surfaces | 2 |
| | quadric surfaces, spline representation, cubic spline interpolation methods, Bazier curves and surfaces | 2 |
| | B-spline curves and surfaces.3D scaling, rotation and translation, composite transformation | 2 |
| | viewing pipeline and coordinates, parallel and perspective transformation | 1 |
| | view volume and general (parallel and perspective) projection transformations. | 1 |
| Unit-6(6) | Light sources – basic illumination models – halftone patterns and dithering techniques | 1 |

| | | |
|---|---|---|
| | Properties of light – Standard primaries and chromaticity diagram | 2 |
| | Intuitive colour concepts – RGB colour model – YIQ colour model – CMY colour model – HSV colour model – HLS colour model | 2 |
| | Colour selection. | 1 |
| Unit-7(6) | Design of Animation sequences – animation function – raster animation – key frame systems – motion specification – morphing – tweening | 3 |
| | Tiling the plane – Recursively defined curves – Koch curves – C curves – Dragons – space filling curves –fractals – Grammar based models – fractals – turtle graphics – ray tracing. | 3 |
| | **Total No. of Lecture** | 42 |

**This schedule is tentative and is subject to minimal changes during teaching.**

## Light source

- When we see any object we see reflected light from that object. Total reflected light is the sum of contribution from all sources and reflected light from other object that falls on the object.
- So that the surface which is not diectly exposed to light may also visible if nearby object is illuminated.

- The simplest model for light source is **point source.** Rays from the source then follows radial diverging paths from the source position.

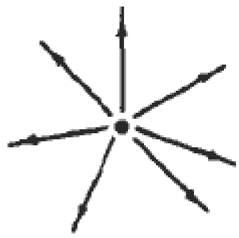

Fig. 6.5:- Diverging ray paths from a point light source.

- This light source model is reasonable approximation for source whose size is small compared to the size of object or may be at sufficient distance so that we can see it as point source. For example sun can be taken as point source on earth.
- A nearby source such as the long fluorescent light is more accurately modelled as a **distributed light source.**
- In this case the illumination effects cannot be approximated with point source because the area of the source is not small compare to the size of object.
- When light is falls on the surface the part of the light is reflected and part of the light is absorbed. Amount of reflected and absorbed light is depends on the property of the object surface. For example shiny surface reflect more light while dull surface reflect less light.

## Basic Illumination Models/ Shading Model/ Lighting Model

- These models give simple and fast method for calculating the intensities of light for various reflections.

### Ambient Light

- This is a simple way to model combination of light reflection from various surfaces to produce a uniform illumination called **ambient light,** or **background light.**
- Ambient light has no directional properties. The amount of ambient light incident on all the surfaces and object are constant in all direction.
- If consider that ambient light of intensity $I_a$ and each surface is illuminate with $I_a$ intensity then resulting reflected light is constant for all the surfaces.

### Diffuse Reflection

- When some intensity of light is falls on object surface and that surface reflect light in all the direction in equal amount then the resulting reflection is called **diffuse reflection.**
- Ambient light reflection is approximation of global diffuse lighting effects.
- Diffuse reflections are constant over each surface independent of our viewing direction.
- Amount of reflected light is depend on the parameter $K_d$, the **diffuse reflection coefficient** or **diffuse reflectivity.**
- $K_d$ is assign value in between 0 and 1 depending on reflecting property. Shiny surface reflect more light so $K_d$ is assign larger value while dull surface assign small value.

- If surface is exposed to only ambient light we calculate ambient diffuse reflection as:
  $I_{ambdiff} = K_d I_a$
  Where $I_a$the ambient light is falls on the surface.
- Practically most of times each object is illuminated by one light source so now we discuss diffuse reflection intensity for point source.

- We assume that the diffuse reflection from source are scattered with equal intensity in all directions, independent of the viewing direction such a surface are sometimes referred as **ideal diffuse reflector** or **lambertian reflector.**
- This is modelled by **lambert's cosine law.** this law states that the radiant energy from any small surface area dA in any direction $\emptyset_n$ relative to surface normal is proportional to $cos\emptyset_n$.

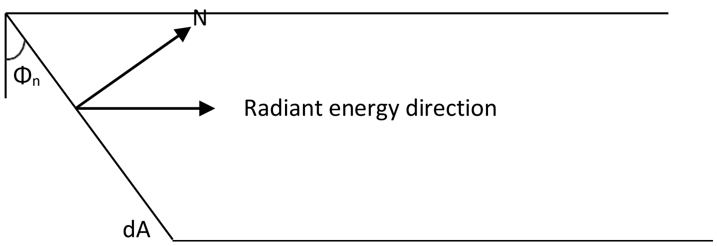


Fig. 6.6:- Radiant energy from a surface area dA in direction $\Phi_n$ relative to the surface normal direction.

- As shown reflected light intensity is does not depends on viewing direction so for lambertian reflection, the intensity of light is same in all viewing direction.
- Even though there is equal light distribution in all direction from perfect reflector the brightness of a surface does depend on the orientation of the surface relative to light source.
- As the angle between surface normal and incidence light direction increases light falls on the surface is decreases

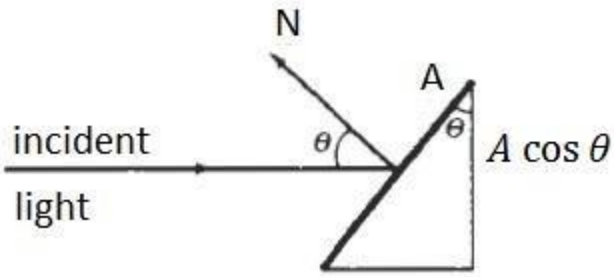


Fig. 6.7:- An illuminated area projected perpendicular to the path of the incoming light rays.

- If we denote the **angle of incidence** between the incoming light and surface normal as$\theta$, then the projected area of a surface patch perpendicular to the light direction is proportional to $cos\theta$.
- If $I_l$ is the intensity of the point light source, then the diffuse reflection equation for a point on the surface can be written as
  $I_{l,diff} = K_d I_l cos\theta$
- Surface is illuminated by a point source only if the angle of incidence is in the range $0^0$ to $90^0$ other than this value of $\theta$ light source is behind the surface.

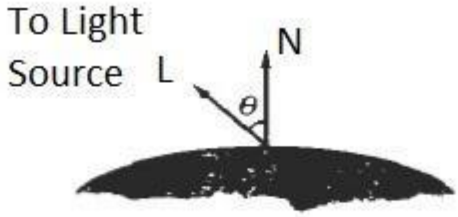


Fig. 6.8:-Angle of incidence $\theta$ between the unit light-source direction vector L and the unit surface normal N.

- As shown in figure **N** is the unit normal vector to surface and **L** is unit vector in direction of light source then we can take dot product of this to is:
  $N \cdot L = \cos\theta$
  And

$I_{l,diff} = K_d I_l (N \cdot L)$

- Now in practical ambient light and light source both are present and so total diffuse reflection is given by:
  $I_{diff} = K_a I_a + K_d I_l (N \cdot L)$
- Here for ambient reflection coefficient $K_a$ is used in many graphics package so here we use $K_a$ instead of $K_d$.

## Specular Reflection and the Phong Model.

- When we look at an illuminated shiny surface, such as polished metal we see a highlight, or bright spot, at certain viewing directions. This phenomenon is called **specular reflection,** is the result of total, or near total reflection of the incident light in a concentrated region around the **specular reflection angle.**

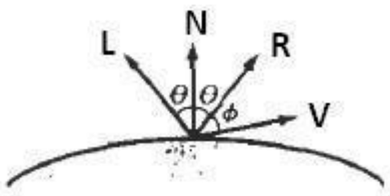


Fig. 6.9:-Specular reflection angle equals angle of incidence $\theta$.

- Figure shows specular reflection direction at a point on the illuminated surface. The specular reflection angle equals the angle of the incident light.
- Here we use R as unit vector in direction of reflection L is unit vector point towards light vector N is unit normal vector and V is unit vector in viewing direction.
- Objects other than ideal reflectors exhibits specular reflection over a finite range of viewing positions around vector R. Shiny surface have a narrow specular reflection range and dull surface have wide specular reflection range.
- **By phong specular reflection model** or simply **phong model** sets the intensity of specular reflection proportional to $cos^{ns}\emptyset$. Angle $\emptyset$ varies in between $0^0$ to $90^0$.
- Values assigned to **specular reflection parameter** ns is determined by the type of surface that we want to display. A shiny surface assigned ns values large nearly 100 and dull surface assigned small nearly 1.
- Intensity of specular reflection depends on the material properties of the surface and the angle of incidence as well as **specular reflection coefficient, $w(\theta)$ for each surfaces.**
- Then specular reflection is given by:
  $I_{spec} = w(\theta) I_l cos^{ns}\emptyset$
  Where $I_l$ is the intensity of light source and $\emptyset$ is angle between viewing direction V and specular reflection direction R.
- Since $\emptyset$ is angle between two unit vector V and R we can put $cos\emptyset = V \cdot R$.
- And also for many surfaces $w(\theta)$ is constant so we take specular reflection constant as $K_s$ so equation becomes.
  $I_{spec} = K_s I_l (V \cdot R)^{ns}$
- Vector r is calculated in terms of vector L and N as shown in figure

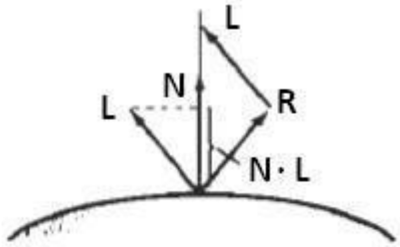


Fig. 6.10:- Calculation of vector R by considering projection onto the direction of the normal vector N.

$R + L = (2N \cdot L)N$

$R = (2N \cdot L)N - L$

- Somewhat simplified phong model is to calculate between half way vectors H and use product of H and N instead of V and R.
- Here H is calculated as follow:

$$H = \frac{L + V}{|L + V|}$$

### Combined Diffuse and Specular Reflections With Multiple Light Sources

- For a single point light source we can combined both diffuse and specular reflection by adding intensity due to both reflection as follows:

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

$I = K_a I_a + K_d I_l (N \cdot L) + K_s I_l (N \cdot H)^{ns}$

- And for multiple source we can extend this equation as follow:

$$I = K_a I_a + \sum_{i=1}^{n} I_l [K_d (N \cdot L) + K_s (N \cdot H)^{ns}]$$

## Properties of Light

- Light is an electromagnetic wave. Visible light is have narrow band in electromagnetic spectrum nearly 400nm to 700nm light is visible and other bands not visible by human eye.

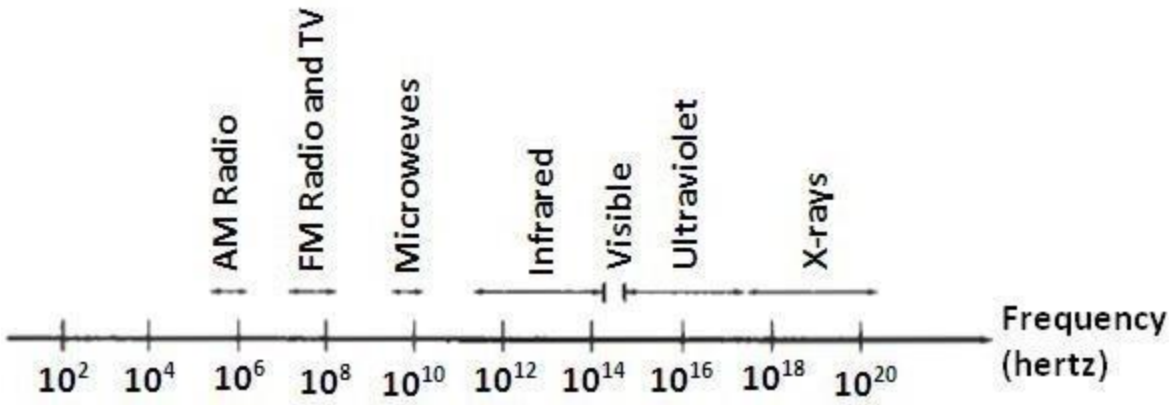


Fig. 6.11:- Electromagnetic spectrum.

- Electromagnetic spectrum shown in figure shows other waves are present in spectrum like microwave infrared etc.
- Frequency value from 4.3 X 10^14 hertz (red) to 7.5 X 10^14 (violet) is visible renge.
- We can specify different color by frequency f or by wavelength λ of the wave.
- We can find relation between f and λ as follows:

$c = \lambda f$

- Frequency is constant for all the material but speed of the light and wavelength are material dependent.

- For producing white light source emits all visible frequency light.
- Reflected light have some frequency and some are absorbed by the light. This frequency reflected back is decide the color we see and this frequency is called as **dominant frequency (hue)** and corresponding reflected wavelength is called **dominant wavelength.**
- Other property are **purity** and **brightness.** Brightness is perceived intensity of light. Intensity is the radiant energy emitted per unit time, per unit solid angle and per unit projected area of the source.
- **Purity** or **saturation** of the light describes how washed out or how "pure" the color of the light appears.
- Dominant frequency and purity both collectively refers as **chromaticity.**
- If two color source combined to produce white light they are called **complementary color** of each other. For example red and cyan are complementary color.
- Typical color models that are uses to describe combination of light in terms of dominant frequency use three colors to obtain reasonable wide range of colors, called the **color gamut** for that model.
- Two or three colors are used to obtain other colors in the range are called **primary colors.**

## XYZ Color Model

- The set of CIE primaries is generally referred to as XYZ or (X, Y, Z) color model.

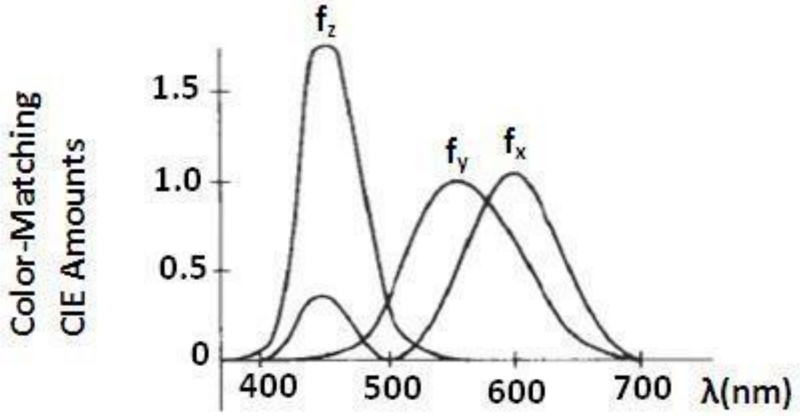


Fig. 6.12:- Amount of CIE primaries needed to display spectral colors.

- X, Y, Z represents vectors in a three dimensional, additive color space.
- Any color $C_\lambda$ is a combination of three primary colors as
  $C_\lambda = XX + YY + ZZ$
  Where X, Y, Z, is the amount of standard primary need to combine for obtaining color $C_\lambda$.
- If we normalize it then.
  $x = \frac{X}{X+Y+Z} \quad y = \frac{Y}{X+Y+Z} \quad z = \frac{Z}{X+Y+Z}$
  With $x + y + z = 1$
- Now we can represent any color with x,y only as z we can find z=1-x-y.
- X, and y are called chromaticity values because they depends only on hue and purity.
- Now if we specify colors with only x, and y values we cannot find amount X, Y, and Z.
- So we specify color with x, y, and Y and rest CIE amount is calculated as:
  $X = \frac{x}{y}Y \quad Z = \frac{z}{y}Y$
  Where z=1-x-y

## RGB Color Model

- Based on tristimulus theory of vision our eye perceives color through stimulate one of three visual pigments in the cones of the retina.

- These visual pigments have peak sensitivity at red, green and blue color.
- So combining these three colors we can obtain wide range of color this concept is used in RGB color model.

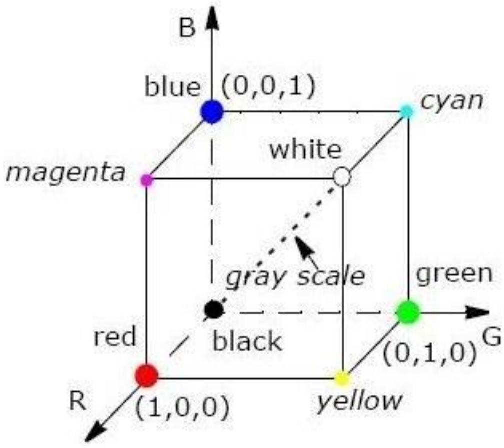


Fig. 6.13:- The RGB color model.

- As shown in figure this model is represented as unit cube.
- Origin represent black color and vertex (1,1,1) is white.
- Vertex of the cube on the axis represents primary color R, G, and B.
- In XYZ color model any color intensity is obtained by addition of primary color.
  $C_{\lambda} = RR + GG + BB$
- Where R, G, and B is amount of corresponding primary color
- Since it is bounded in between unit cube it's values is very in between 0 to 1 and represented as triplets (R,G,B). For example magenta color is represented with (1,0,1).
- Shades of gray are represented along the main diagonal of cube from black to white vertex.
- For half way gray scale we use triplets (0.5,0.5,0.5).

## YIQ Color Model

- As we know RGB monitors requires separates signals for red, green, and blue component of an image but television monitors uses single composite signals.
- For this composite signal NTSC use YIQ color model.
- Here parameter Y is represented as luminance (brightness) while chromaticity information (hue and purity) is specified into I and Q parameter.
- Combination of all red, green, and blue intensities are chosen for Y so black and white television monitors only use signal Y for brightness.
- So largest bandwidth (about 4 MHz) is assigned to Y information signal.
- Parameter I contain orange-cyan hue information that provides the flash-tone shading, and occupies a bandwidth approximately 1.5 MHz.
- Parameter Q carries green-magenta hue information in a bandwidth of about 0.6 MHz.
- An RGB signal can be converted to a television signal using encoder which converts RGB to YIQ values.
- This conversion by transformation is given by:
  $$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$
- Similarly reverse of this is performed by decoder and by transformation using inverse of above matrix as.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.000 & 0.956 & 0.620 \\ 1.000 & -0.272 & -0.647 \\ 1.000 & -1.108 & 1.705 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix}$$

## CMY Color Model

- A color model CMY is used for hardcopy devices as we produce picture by coating a paper with color pigments, we see the color by reflected light a subtractive process.
- When white light is reflected from cyan colored ink the reflected light must have no red component that is red light is absorbed or subtracted by the ink.
- Similarly magenta is subtracting green component.
- Unit cube for CMY model is shown in figure below.

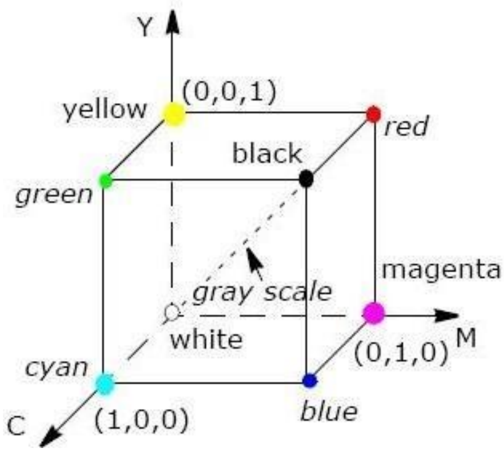


Fig. 6.14:- The CMY color model.

- Point (1,1,1) represents black because all components are subtracts and origin represents white light.
- Gray can be produce among main diagonal by using all three color in equal amount.
- Printing process often use CMY model generates a color points with a collection of four ink dots, one for each primary color C, M, and Y and one dot is black.
- Conversion of RGB to CMY is done by:

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

- And similarly reverse is done by:

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