UNIT7: <Illumination and shading> ①

→ **Illumination models**: is used to calculate the intensity of light that is reflected at given point on surface.

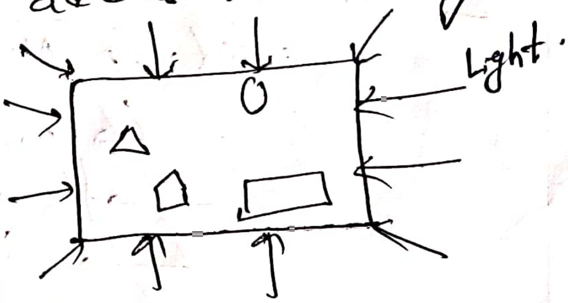
→ An object is illuminated from the ambient light & from interrelated ~~and~~ light source.

→ The different & important illuminations models are
- Ambient Light (Light coming from the nearby objects after reflection).
- Diffuse illumination
- Specular reflection.

→ Object illuminates on the basis of following properties:
1> Intensity of Ambient Light
2> Types of object surface
3> Surface color.

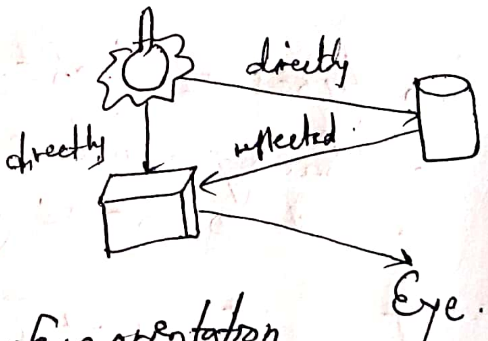
* **Ambient Light**: The equal amount of light from all directions.
(background light)

→ It means the light that is already present in a scene, before any additional lighting is added. It usually refers to natural light.



→ The amount of ambient light incident on each object is a constant for all the surfaces and over direction.

→ The amount of ambient light incident on surface depends on
- Type of materials.



→ Modeling Ambient Light
Ia = ambient intensity parameter.

→ Ambient light is independent of → Surface orientation → Viewer location.

→ But the different surfaces may reflect different amount of ambient light. $[I_{amb} = K_a \cdot I_a]$ where I_a = intensity of ambient light, K_a = percentage of light reflected by object.

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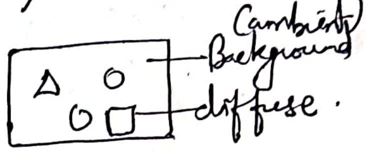
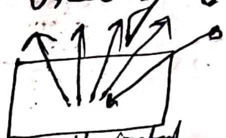
Diffuse Reflection: The light is reflected in all directions is called diffuse reflection.

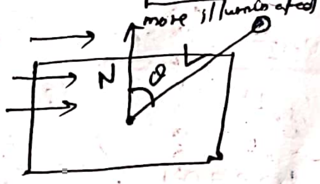
- The reflected light is independent of viewing position. {equally bright from all direction}.
- But the light position with respect to surface orientation is important.
- Surface orientation is dependent.



- Modeling diffuse Reflection.
  - The diffuse surface are either rough or grainy like clay, soil, fabric.
  - The surface appears equally bright from all viewing directions.



  - The brightness at each point is proportional to $\cos\theta$.



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

$$= k_d \cdot I_p (N \cdot L)$$

- I_p → point of light intensity
- k_d → surface diffuse reflection (0 to 1) [0, 1]
- N → Surface normal
- L → Light direction.

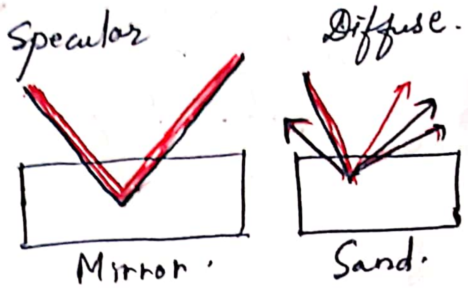
- Two types of light sources
  - Background ambient light
  - A point of light source

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

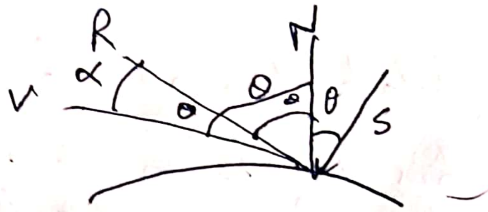
$$I = K_d I_p \cdot N \cdot L + K_a I_a$$

Specular Reflection: It is white highlight reflection seen on smooth shiny objects.

→ Depends on → $\boxed{\text{Surface normal}}$ (orientation)
→ $\boxed{\text{Viewer location}}$.



→ Examples of specular reflections are
i) Metal surfaces
ii) Mirrors
iii) Shiny plastic.
iv) Gold & silver coated surfaces



→ Modeling Specular Reflection

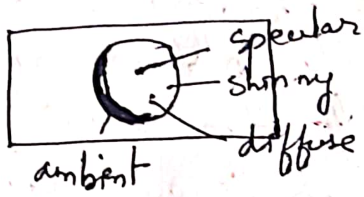
R = Reflection vector.

$I_{sp} = I \times K_d \cos^n \alpha$

$n \rightarrow$ specular intensity

$R \rightarrow 2N(N \cdot S) - S$

$\cos \alpha = R \cdot V$



Combination of all Ambient, specular & Diffuse light is

$$\left[I = I_{amb} + I_{diff} + I_{sp} \right]$$

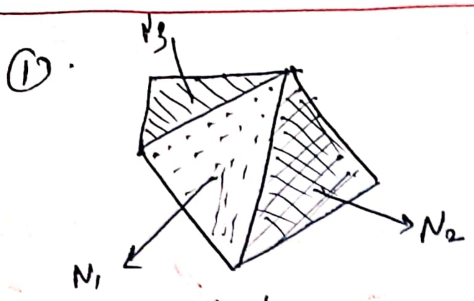
<Surface Shading Methods>

- Shading is referred to as the implementation of the illumination model at the pixel points or polygon surfaces of the graphics objects.
- Used to compute intensities & color to display the surface

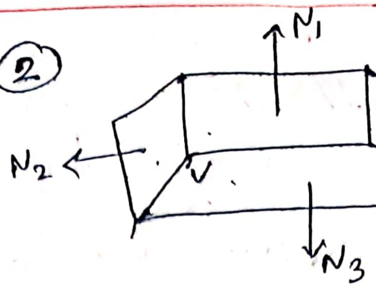
★ **<Shading Models>**: Determines where the lighting model is applied.

① Flat / Constant Shading
② Gouraud Shading
③ Phong Shading
④ Fast Phong Shading

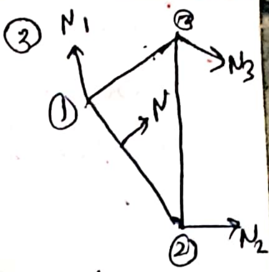
(② – ④)] Interpolation Method.

1.


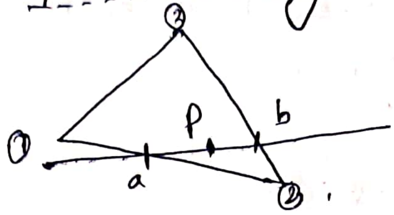
Constant shading

2


Gauraud Shading

3


Phong shading



1) Flat Shading / Constant Intensity Shading

- This is the most simple and very fast method to specify color for an object.
- Flat shading of a polygon assumes that each polygon is strictly planar and all the points on the polygon have exactly the same kind of lightning treatment.
- This shading technique thus displays all the points in a polygon with a single color.
- It defines a single color for a face implementation of it vary but main idea is that we use only one surface normal polygon.
- Discontinuity of colors can be observed in different faces of polygon.

2) Gouraud Shading

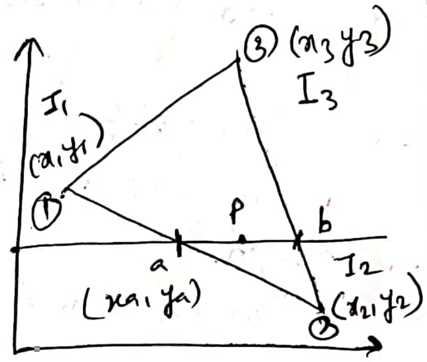
- This was invented as an improvement to allow for more smooth transitions of the color on round objects.
- It is the form of interpolation shading.
- Intensity levels are calculated at each vertex and interpolated across the surface.
- This intensity interpolation scheme renders the polygon surface by linearly interpolating intensity values across the surface. Intensity values for each polygon are matched with the values of adjacent polygons along the common edges.

→ Thus it eliminates the intensity discontinuities that occurs in flat shading.

→ This techniques uses the concept of intensity interpolation, hence it is also known as intensity interpolation or color interpolation shading.

Gouraud Shading Algorithm :

① Determine the average unit normal vector at each polygon vertex.



$$N_v = \frac{N_1 + N_2 + N_3}{|N_1 + N_2 + N_3|}$$

$$= \frac{\sum_{i=1}^{n} N_i}{\left|\sum_{i=1}^{n} N_i\right|}$$

n = no. of surfaces of polygon sharing that vertex.

② By illumination we get Intensity of each vertex

→ Intensity of a : $I_a = \frac{y_a - y_2}{y_1 - y_2} I_1 + \frac{y_1 - y_a}{y_1 - y_2} I_2$

→ Intensity of b : $I_b = \frac{y_b - y_2}{y_2 - y_3} I_3 + \frac{y_3 - y_b}{y_1 - y_2} I_2$

③ Linearly interpolate the vertex intensities over the surface of polygon.

→ Intensity at point P is given by

$$\left[I_p = \frac{x_b - x_p}{x_b - x_a} I_a + \frac{x_p - x_a}{x_b - x_a} I_b \right]$$

* Advantages of Gouraud Shading Model:

→ The discontinuity in intensities in a constant intensity shading model are removed.

→ To fill in the visible polygons along each scan line this model can be combined with a hidden surface algorithm.

→ Disadvantages of Gouraud Shading

→ Sharp drop of intensity values on the polygon surface cannot be displayed.

→ Highlights on the surface are sometimes displayed with anomolous shape

→ Bright & Dark streaks appearing on the surface known as mach bands.

(3). Phong Shading

→ A more accurate interpolation based approach for rendering a polygon was developed by Phong Bui Tuong.

→ Phong shading improves upon Gouraud shading and provides a better approximation of the shading of a smooth surface.

→ It interpolates normal vectors instead of intensity values.

* [Algorithm]

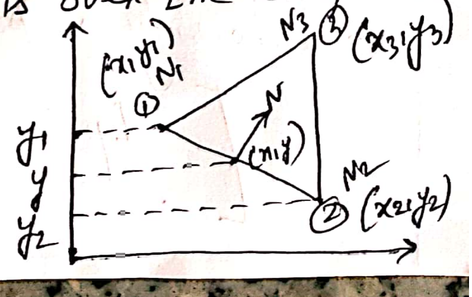
→ Determine the average unit normal vector at each polygon vertex.

$$N_v = \frac{N_1 + N_2}{|N_1 + N_2|} = \frac{\sum^{n} N_i}{\left|\sum_{i=1} N_i\right|}$$

n = no. of surface sharing vertex.

→ Linearly interpolate the vertex normals over the surfaces of polygon.

→ $$N = \frac{y - y_2}{y_1 - y_2} N_1 + \frac{y_1 - y}{y_1 - y_2} N_2$$



→ Apply the Illumination model along each scan to determine projected pixel intensities of surface points.

→ Advantages

- Linear intensity interpolation causes dark and bright intensity streaks known as mach bands to appear on the surface, this method reduces the mach band effects and display more realistic highlights.

→ It is more accurate than Gouraud Shading.

→ Disadvantages:

- It is slower than Gouraud Shading
- It requires calculation, hence greatly increases cost of shading at each successive step.

4) Fast Phong Shading: Fast Phong shading approximates the intensity calculations using a Taylor series expansion and Triangular surface patches.

Since Phong shading interpolates normal vectors from vertex normals, we can express the surface normal N at any point (x, y) over a triangle as

$$N = Ax + By + C$$

where A, B, C are determined from the three vertex equation.

$$N_K = \cancel{Ax_K}\ Ax_K + BY_K + C, \quad K = 1, 2, 3 \text{ for } (x_k, y_k) \text{ vertex.}$$

→ Omitting the reflectivity & attenuation parameters

$$I_{diff}(x, y) = \frac{L \cdot N}{|L| \cdot |N|} = \frac{L \cdot (Ax + By + C)}{|L| \cdot |Ax + By + C|} = \frac{(L \cdot A)x + (L \cdot B)y + (L \cdot C)}{|L| \cdot |Ax + By + C|}$$

Color Models

→ It is simply a way to define color.

→ A model describes how color will appear on the computer screen or on paper.

→ Two popular color models are

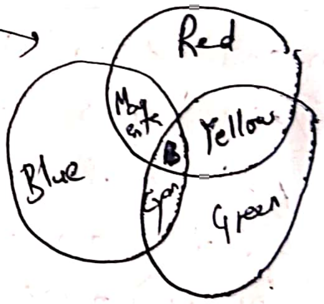
1. RGB (Red, Green, Blue)
2. CMYK (Cyan, Magenta, Yellow, Black).

1) RGB: Used when working with screen based designs.

→ A value between 0 and 255 is assigned to each of the light colors, Red, Green & Blue.

→ If we want to create a purely Blue color, then, Red will also have value 0 but would have value 0 and Green will have value 255. Blue will have value 255.

→ It is also called "Additive" model and is opposite to subtractive model.



2) CMYK: used for print work.

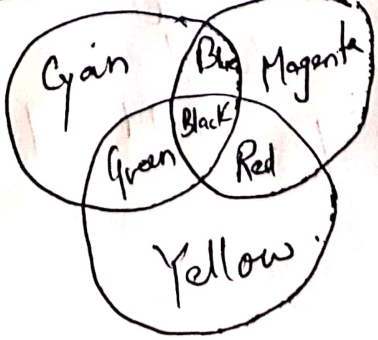
→ It describes colors based on their percentage of Cyan, Magenta, Yellow & Black.

→ Used by commercial printers & bureaus. (home printers also)

→ Used to reproduce full color artwork in magazines, books and brochures.

→ By combining CMYK, illusion of lot of colors can be created.

→ Known as "subtractive" color model.



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