

# Illumination Models & Surface Rendering

By

Poonam Saini

Dept. of Computer Science & Engineering

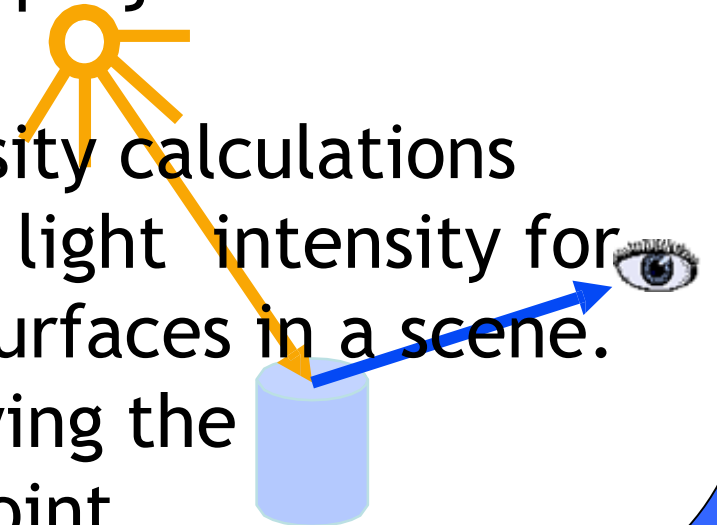
Sir Padampat Singhanian University

Udaipur

# Illumination Models & Surface Rendering

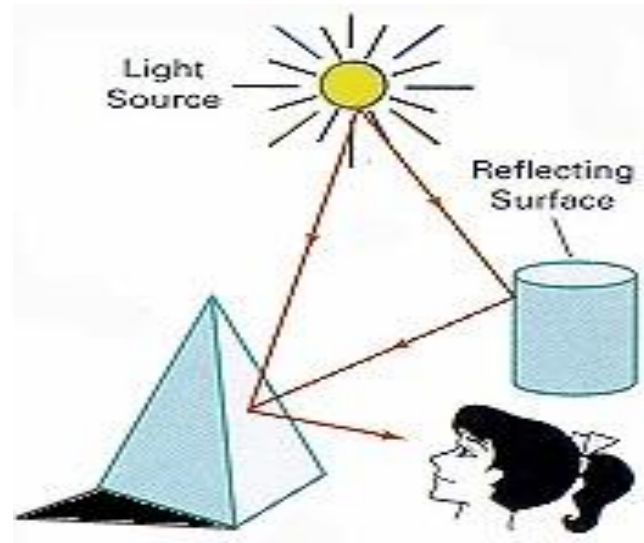
# Basic Illumination Models

- An illumination model, also called a lighting model and sometimes referred to as a shading model, is used to calculate the **intensity of light** that we should see at a given point on the surface of an object.
- Surface rendering means a **procedure for applying a lighting model to obtain** pixel intensities for all the projected surface positions in a scene.
- A surface-rendering algorithm uses the intensity calculations from an illumination model to determine the light intensity for all projected pixel positions for the various surfaces in a scene.
- Surface rendering can be performed by applying the illumination model to every visible surface point



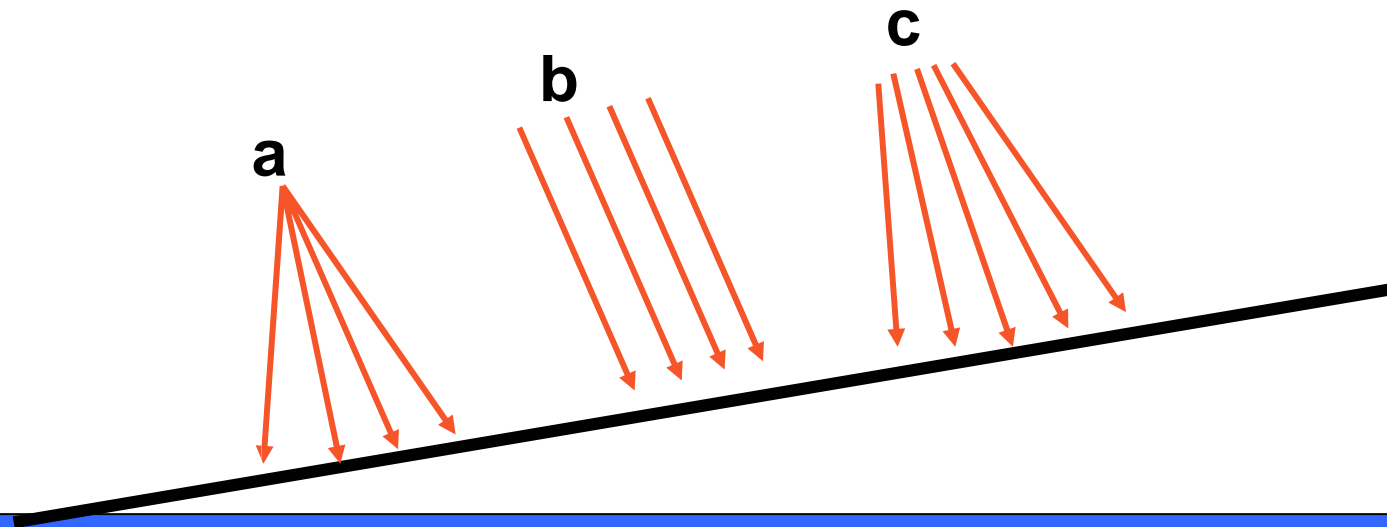
# Illumination Models & Rendering

- An **illumination model** is used to calculate the intensity of the light that is reflected at a given point on a surface
- A **rendering method** uses intensity calculations from the illumination model to determine the light intensity at all pixels in the image



# Light Sources

- **Point Source** (a): All light rays originate at a point and radially diverge. A reasonable approximation for sources whose dimensions are small compared to the object size
- **Parallel source** (b): Light rays are all parallel. May be modeled as a point source at infinite distance (the sun)
- **Distributed source** (c): All light rays originate at a finite area in space. It models a nearby source, such as a fluorescent light.



# Light Sources

- 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.
- for an illuminated transparent surface, some of the incident light will be reflected and some will be transmitted through the material

# Reflection

- Surfaces that are rough, or grainy, tend to scatter the reflected light in all directions. This scattered light is called **diffuse reflection**.
- 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

# Basic Illumination Models

- Simplified and fast methods for calculating surfaces intensities, mostly empirical
- Calculations are based on optical properties of surfaces and the lighting conditions (no reflected sources nor shadows)
- Light sources are considered to be point sources
- Reasonably good approximation for most scenes

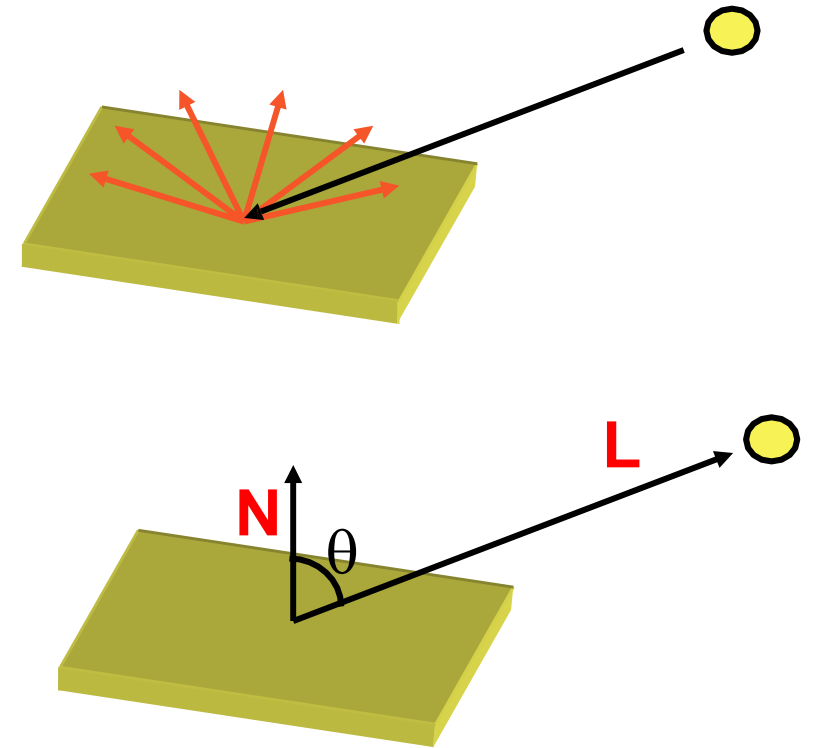


# Basic Illumination Models: Ambient Illumination

- In our basic illumination model, we can set a general level of brightness for a scene. This is a simple way to model the combination of light reflections from various surfaces to produce a uniform illumination called the ambient light, or background light.
- Assume there is some non-directional light in the environment (background light)
- The amount of ambient light incident on each object is constant for all surfaces and over all directions
- Very simple model, not very realistic

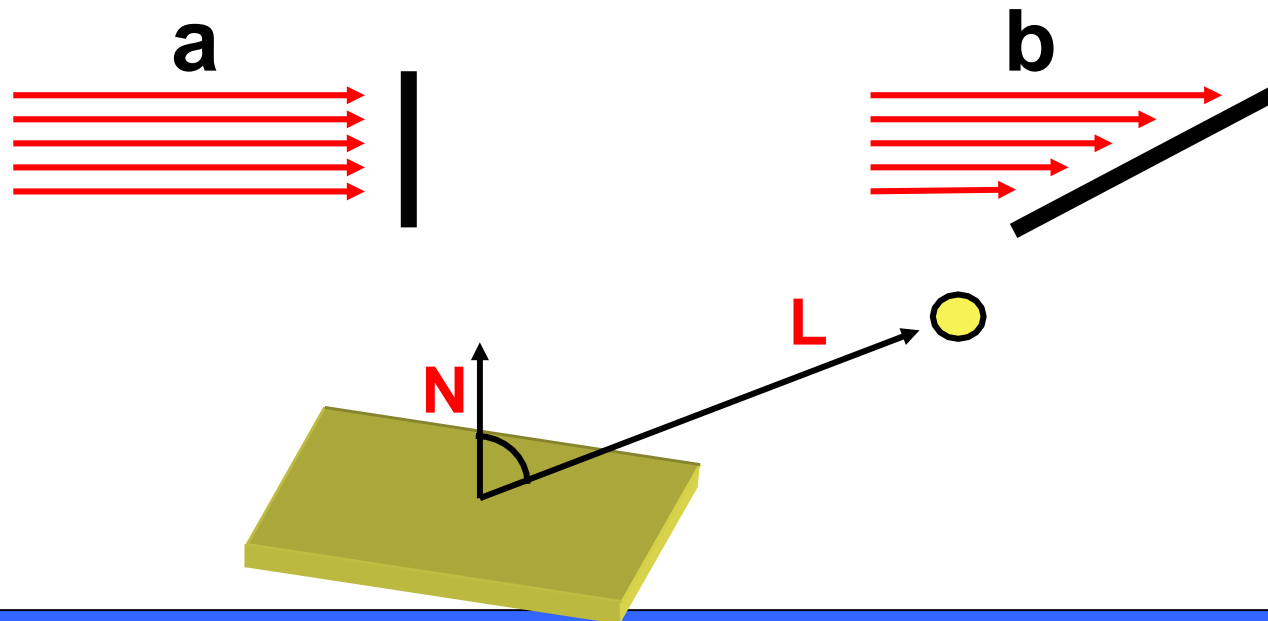
# • Basic Illumination Models: Diffuse Reflection

- Diffuse (Lambertian) surfaces are rough or grainy, like clay, soil, fabric
- The surface appears equally bright from all viewing directions
- The brightness at each point is proportional to  $\cos(\theta)$



# • Basic Illumination Models: Diffuse Reflection

- Brightness is proportional to  $\cos(\theta)$  because a surface (a) perpendicular to the light direction is more illuminated than a surface (b) at an oblique angle



# •Basic Illumination Models: Diffuse Reflection

- The reflected intensity  $I_{\text{diff}}$  of a point on the surface is:

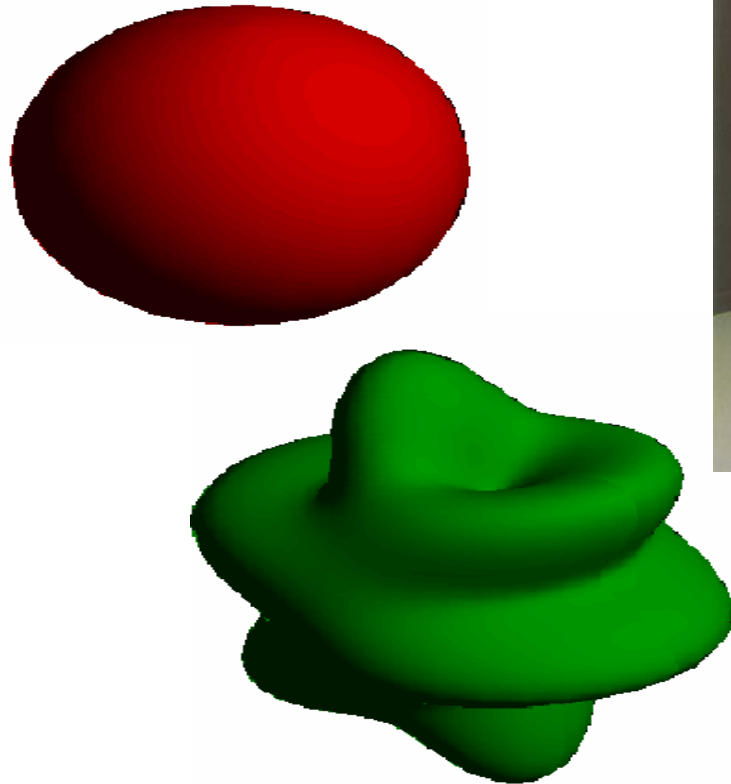
$$I_{\text{diff}} = K_d I_p \cos(\theta) = K_d I_p (N \cdot L)$$

Where  $I_p$  - the point light intensity. May appear as attenuated source  $f_{\text{att}}(r)I_p$   
 $K_d \in [0,1]$  - the surface diffuse reflectivity  
 $N$  - the surface normal  
 $L$  - the light direction

NOTE: If  $N$  and  $L$  have unitary length:  $\cos(\theta) = N \cdot L$

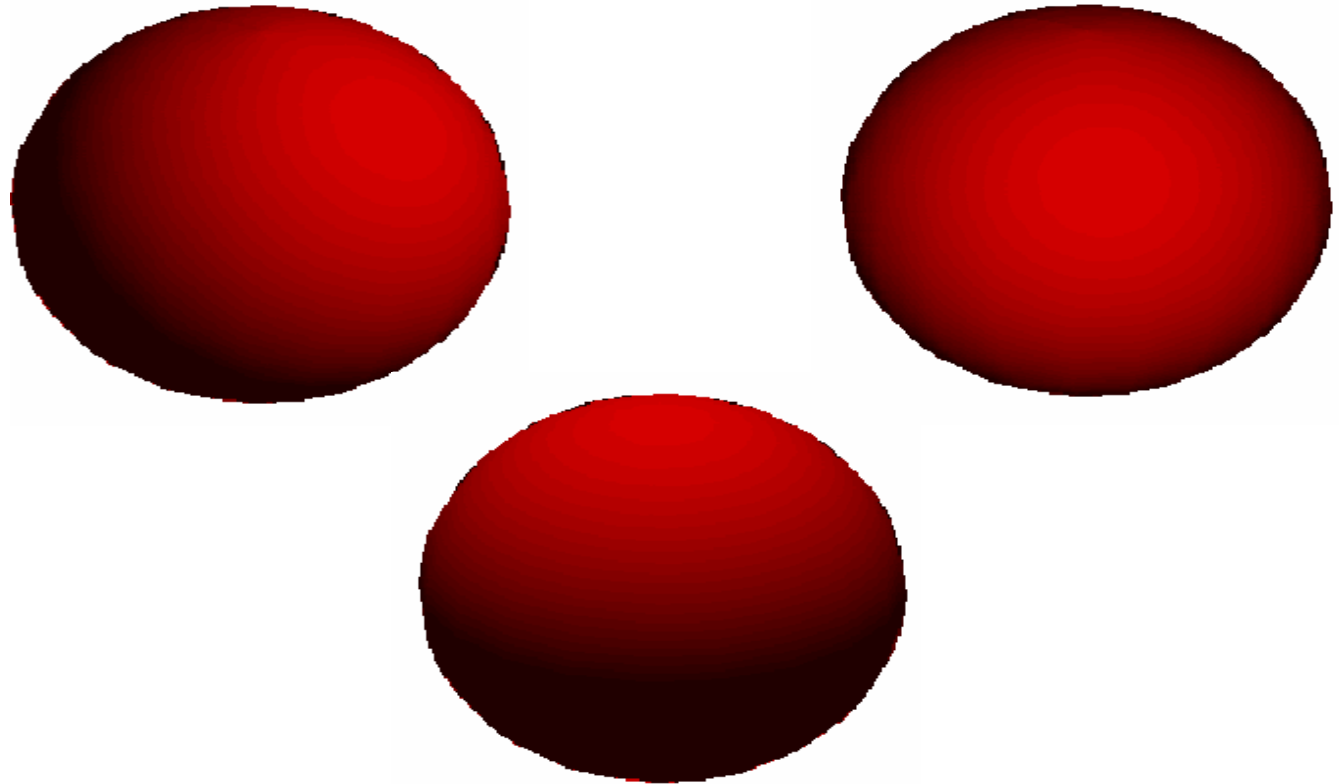
# • Basic Illumination Models: Diffuse Reflection Example

- 



- **Basic Illumination Models: Diffuse Reflection**

**Example:** diffuse reflection from different light directions



# • Basic Illumination Models: Diffuse Reflection

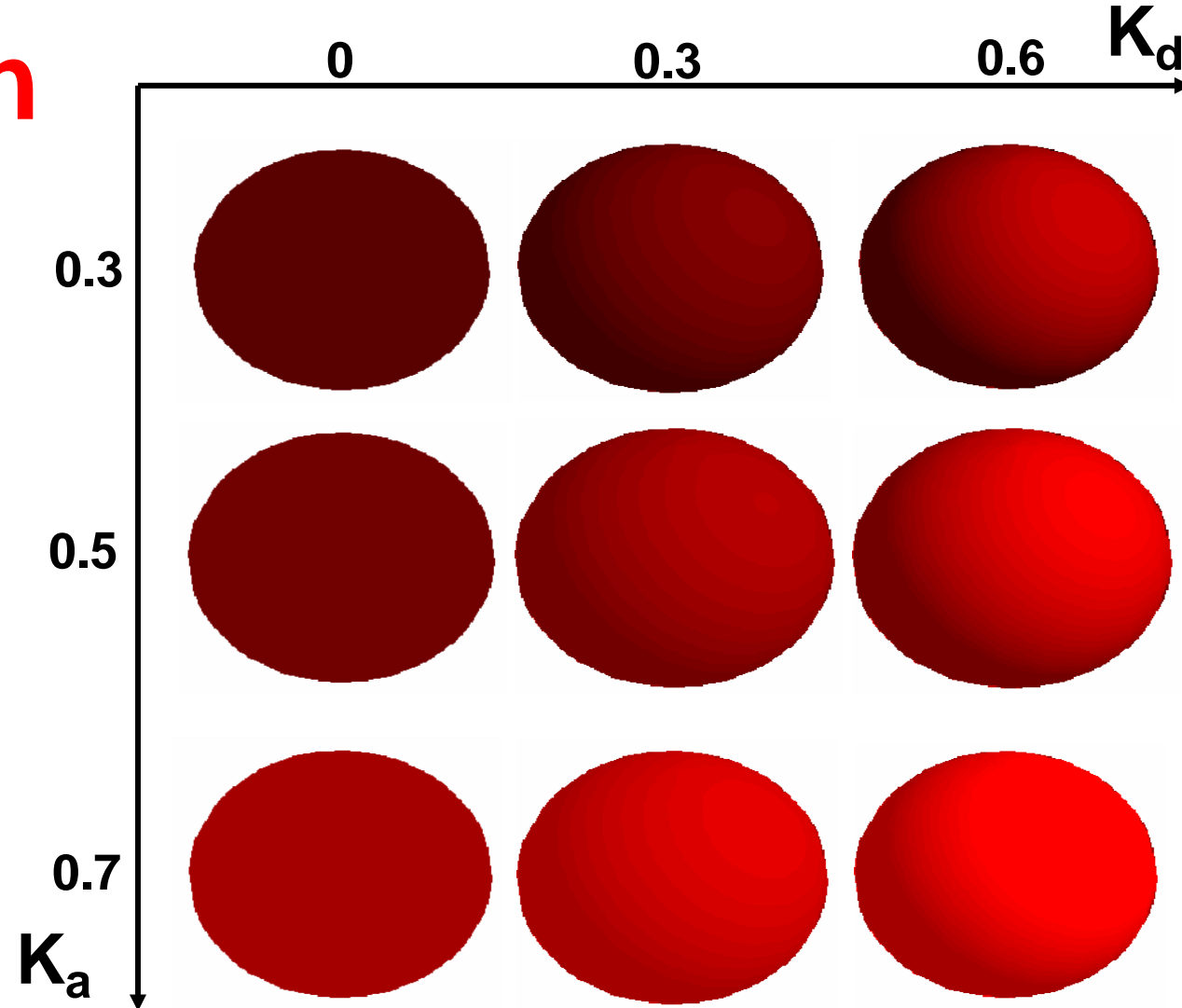
- Commonly, there are two types of light sources:
  - A background ambient light
  - A point light source
- The equation that combines the two models is:

$$I = I_{\text{diff}} + I_{\text{amb}} = K_d I_p \mathbf{N} \cdot \mathbf{L} + K_a I_a$$

- Note this is the model for one color and it should be replicated for each channel:  $I^R$ ,  $I^G$  and  $I^B$

# •Basic Illumination Models: Diffuse Reflection

Example:



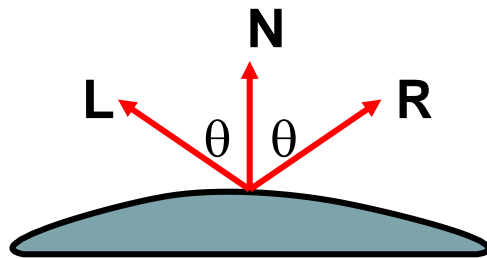


# • **Basic Illumination Models: Specular Reflection**

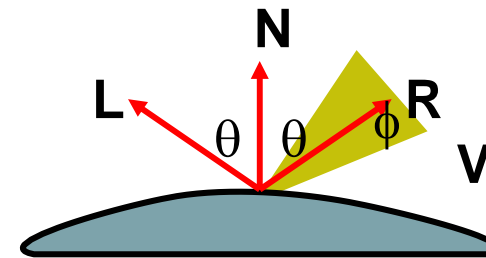
- **We see a highlight, or bright spot, at certain viewing directions.** This phenomenon, called **specular reflection**, is the result of **total, or near total** reflection of the incident light in a concentrated region around the specular reflection angle.
- The specular-reflection angle equals the angle of the incident light

# • Basic Illumination Models: Specular Reflection

- Reflectance intensity changes with reflected angle
- An ideal specular surface (mirror) reflects light exclusively in one direction:  **$R$**
- Glossy objects are not ideal mirrors and reflect in the immediate vicinity of  $R$



Ideal specular surface



Non-ideal specular surface

- **Basic Illumination Models: Specular Reflection**

- **The Phong Model:** reflected specular intensity falls off as some power of  $\cos(\phi)$ :

$$I_{\text{spec}} = K_s I_p \cos^n(\phi) = K_s I_p (R \cdot V)^n$$

$K_s$  - the surface specular reflectivity

$n$  – specular reflection parameter, determining the deviation from ideal specular surface  
(for a perfect mirror  $n = \infty$ )

- **Basic Illumination Models: Specular Reflection**

- The illumination equation combined with diffuse reflection is:

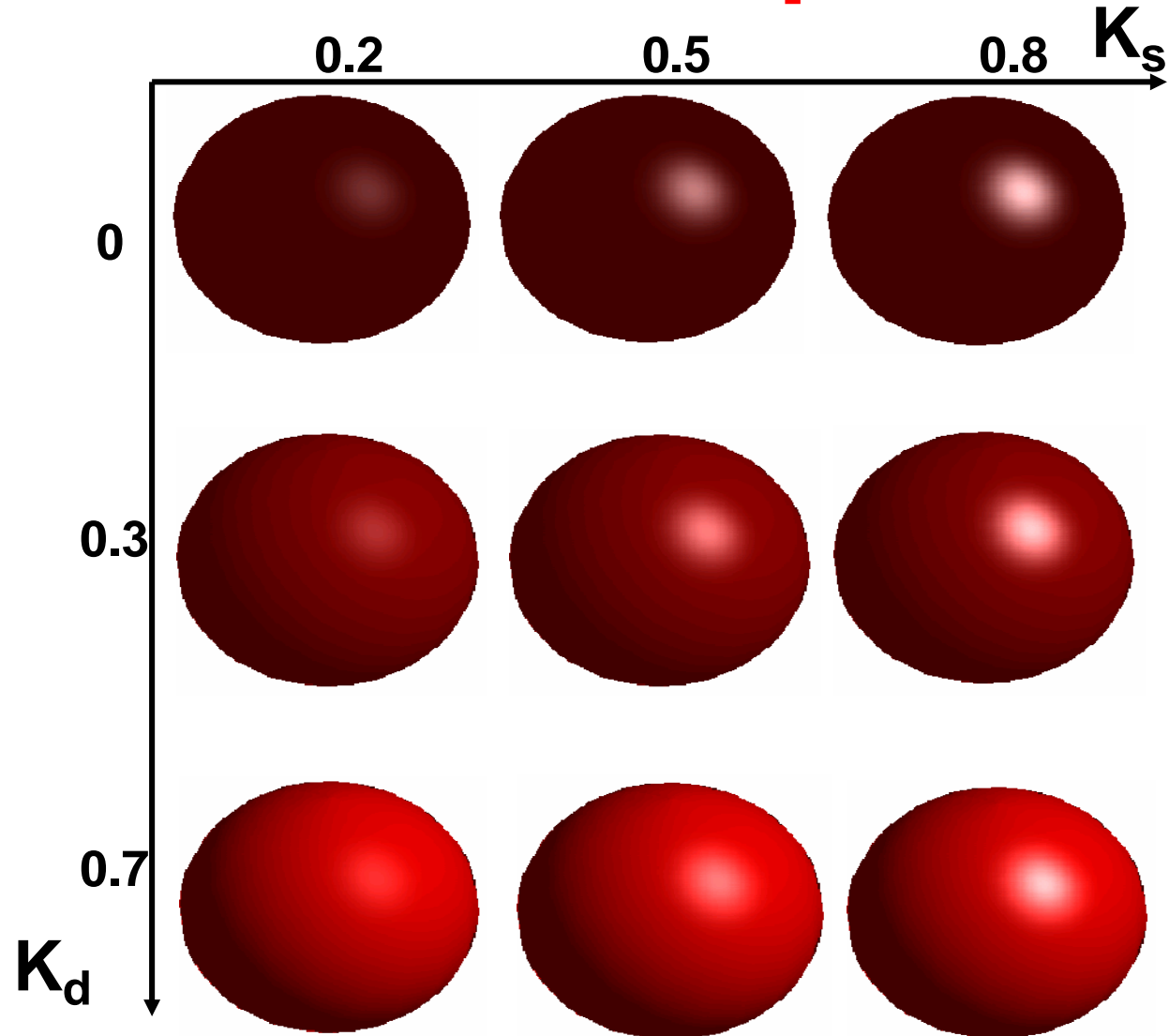
$$I = I_{\text{amb}} + I_{\text{diff}} + I_{\text{spec}} = K_a I_a + I_p (K_d N \cdot L + K_s (R \cdot V)^n)$$

If **k** light sources are present in the scene:

$$I = I_{\text{amb}} + \sum_k (I^k_{\text{diff}} + I^k_{\text{spec}})$$

# • Basic Illumination Models: Specular Reflection

Example

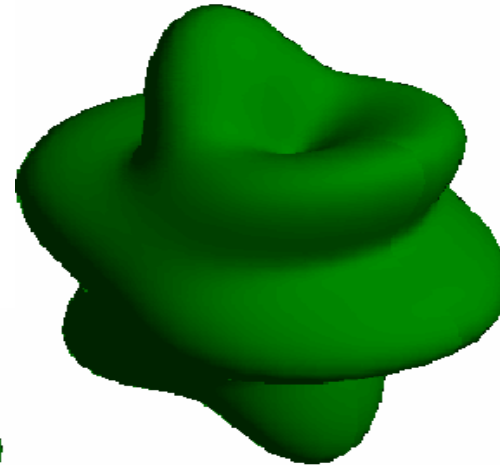


# •Basic Illumination Models: Specular Reflection

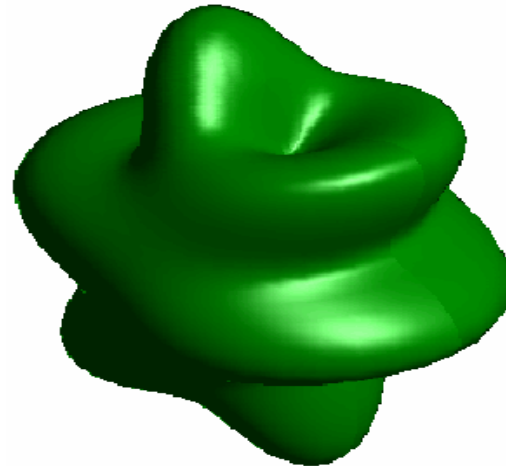
## Example



Ambient Illumination



Ambient + Diffuse



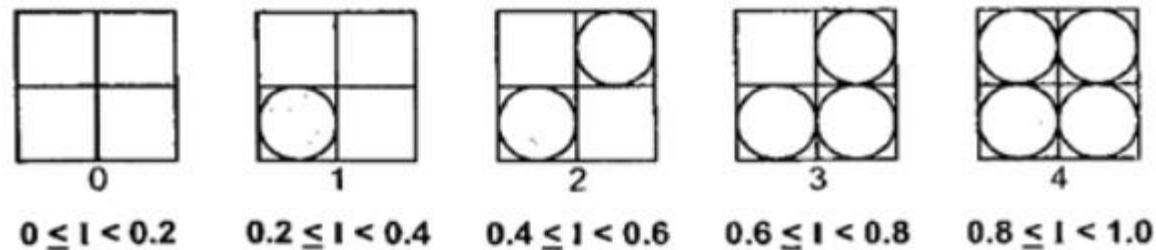
Ambient + Diffuse + Specular

# Half tonning Technique

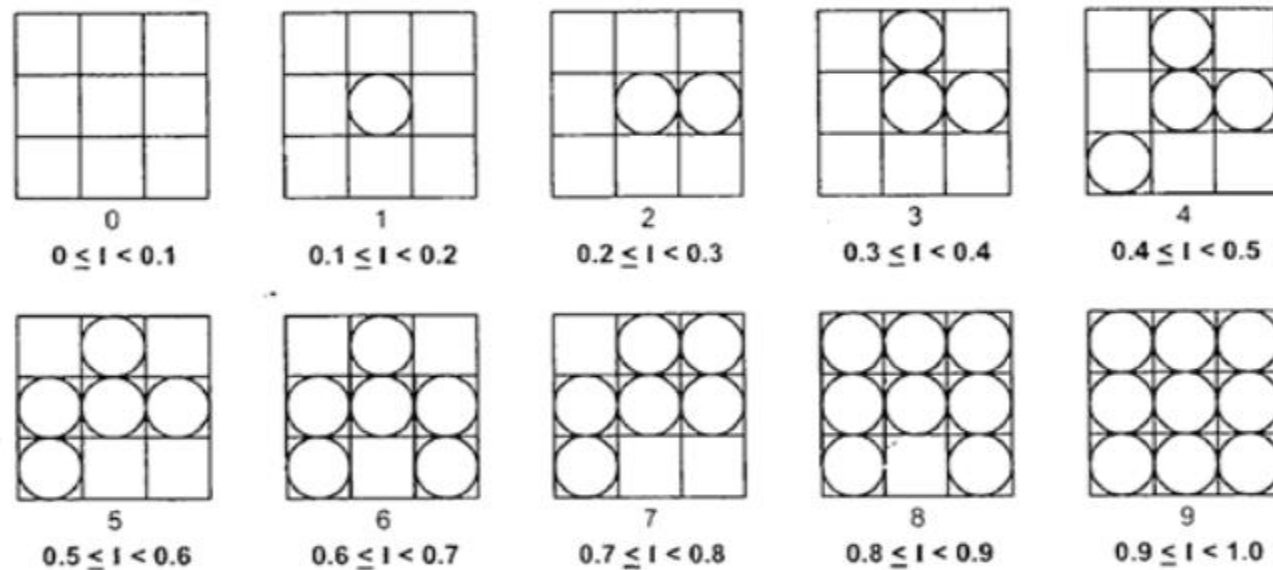
1. Newspaper, photographs simulate a grey-scale image that can be printed using only black ink.
2. A newspaper picture is, in fact, made up of a pattern of tiny black dots of varying size.
3. The human visual system has a tendency to average brightness over small areas, so the black dots and their white background merge and are perceived as an intermediate shade of grey.
4. The process of generating a binary pattern of black and white dots from an image is termed half toning.
5. In traditional newspaper and magazine production, this process is carried out photographically by projection of a transparency through a 'halftone screen' onto film.
6. The screen is a glass plate with a grid etched into it.
7. Different screens can be used to control the size and shape of the dots in the half toned image.
8. In computer graphics, half toning reproductions are approximated using rectangular pixel regions say 2 x 2 pixels or 3 x 3 pixels.
9. These regions are called as "Halftone Patterns" or "Pixel Patterns".

# Half tonning Technique

10. 2 x 2 pixel patterns for creating five intensity levels are shown in figure



3 x 3 pixel patterns for creating ten intensity levels as shown in figure

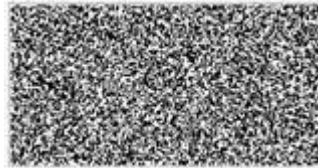




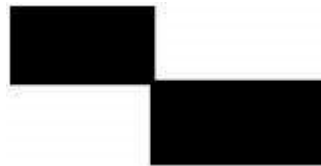
# Dithering Technique

Dithering is the process by which we create illusions of the color that are not present actually. It is done by the random arrangement of pixels.

For example. Consider this image.



This is an image with only black and white pixels in it. Its pixels are arranged in an order to form another image that is shown below. Note at the arrangement of pixels has been changed, but not the quantity of pixels.



# Dithering Technique

When we perform quantization, to the last level, we see that the image that comes in the last level (level 2) looks like this.



Now as we can see from the image here, that the picture is not very clear, especially if you will look at the left arm and back of the image of the Einstein. Also this picture does not have much information or detail of the Einstein.

Now if we were to change this image into some image that gives more detail than this, we have to perform dithering.

# Perform Dithering

Dithering is usually working to improve thresholding.

During thresholding, the sharp edges appear where gradients are smooth in an image.

In thresholding, simply choose a constant value. All the pixels above that value are considered as 1 and all the value below it are considered as 0.

The image after thresholding is shown below:



Since there is not much change in the image, as the values are already 0 and 1 or black and white in this image.

# Perform Dithering

Perform some random dithering to the image. The image below gives slighter of the more details, but its contrast is very low.



Apply some more dithering that will increase the contrast. The image that we got is this:



# Perform Dithering

Now mix the concepts of random dithering, along with threshold and we got an image like this.



We got all these images by just re-arranging the pixels of an image. This re-arranging could be random or could be according to some measure.

# Polygon Rendering methods

- Rendering means representation.
- The objects are usually polygon-mesh approximation of curved surface objects. Scan line algorithm apply a lighting model to obtain polygon surface rendering in one of the two ways.
- Each polygon can be rendered with a single intensity or the intensity can be obtained at each point of the surface using an interpolation scheme.
- Following methods are used for polygon rendering:
  - Constant Intensity shading
  - Gouraud shading
  - Phong shading

# Constant Intensity Shading/Flat shading

- It is a fast and simple method for rendering an object with polygon surfaces is constant intensity shading.
- In this method, a single intensity is calculated for each polygon.
- All points over the surface of the polygon are then displayed with the same intensity value.
- It is useful for quickly displaying the general appearance of a curved surface as in fig.

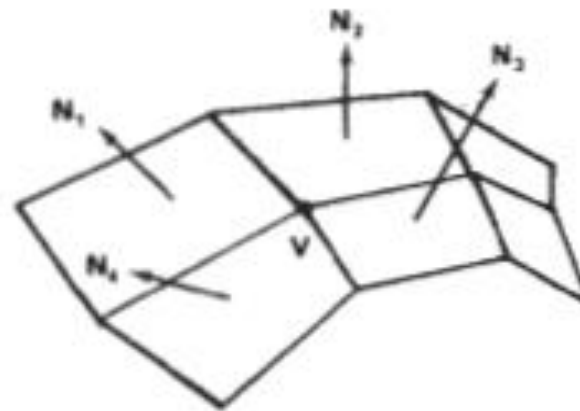


Figure 14-44

The normal vector at vertex V is calculated as the average of the surface normals for each polygon sharing that vertex.

# Constant Intensity Shading/Flat shading

- Flat shading provides an accurate rendering for an object if all of the following assumptions are valid:
  - The object is a polyhedron and is not an approximation of an object with a curved surface.
  - All light sources illuminating the object are sufficiently far from the surface so that N.L and attenuation are constant over the surface.
  - The viewing position is sufficiently far from the surface so that V.R is constant over the surface.



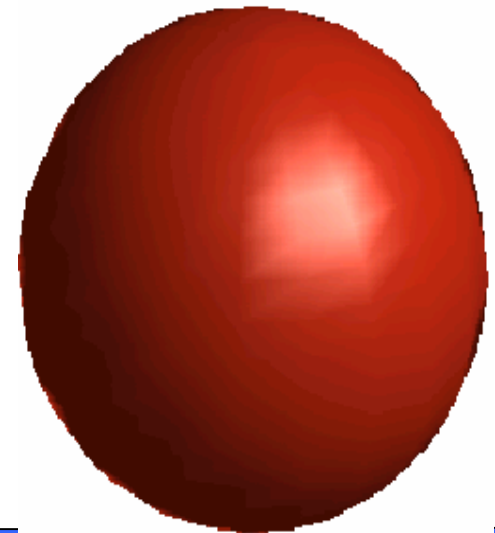


# Gouraud Shading

- It is a intensity interpolation scheme.
- It renders a 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 eliminating the intensity discontinuities that can occur in flat shading.

# Gouraud Shading Algorithm

1. Determine the normal at each polygon vertex
2. Apply an illumination model to each vertex to calculate the vertex intensity
3. Linearly interpolate the vertex intensities over the surface polygon



# Phong Shading

- Phong shading or normal vector interpolation shading is a more accurate method for rendering a polygon surface by interpolating normal vectors and then apply the illumination model to each surface point.
- Phong Shading Algorithm:
  1. Determine the average unit normal vector at each polygon vertex.
  2. Linearly interpolate the vertex normal over the surface of the polygon.
  3. Apply an illumination model along each scan line to calculate projected pixel intensities for the surface point.

# Phong Shading

- The normal vector  $N$  for the scan line intersection point along the edge between vertices  $V_1$  and  $V_2$  can be obtained by vertically interpolating between edge point normals for the figure shown here.

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

Incremental methods are used to evaluate normals between scan lines and along each individual scan line.

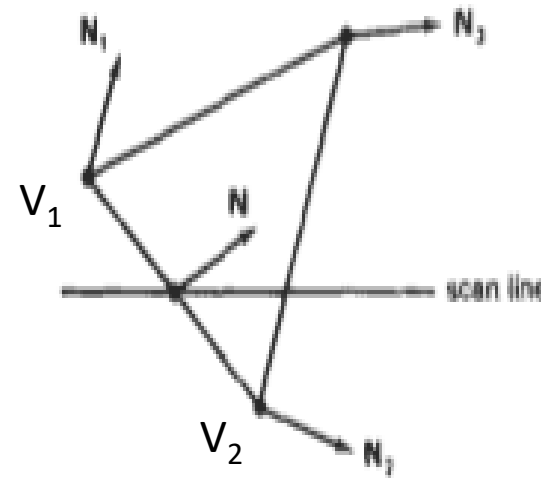
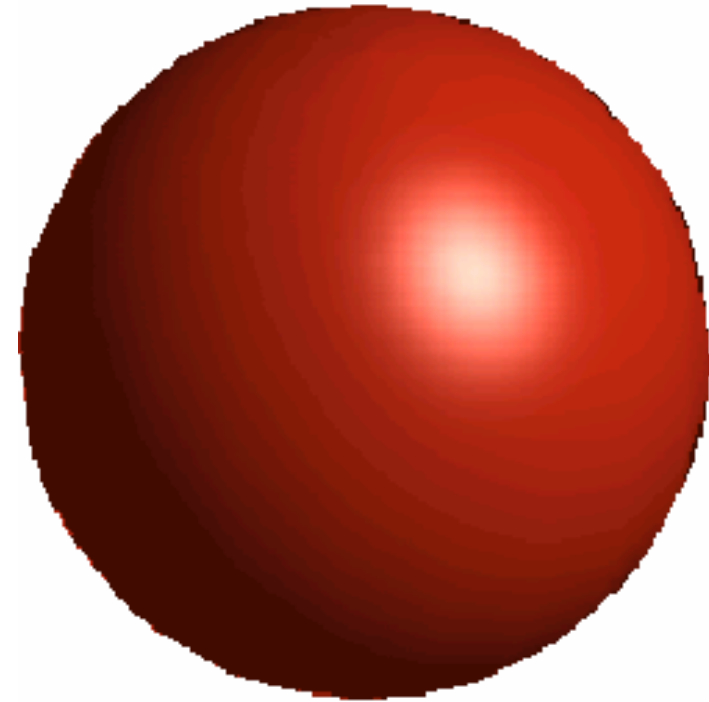


Figure 14-48  
Interpolation of surface normals  
along a polygon edge

# Phong Shading

- At each pixel position along a scan line, the illumination model is applied to determine the surface intensity at that point.
- It provides more accurate results.
- It requires more calculations.

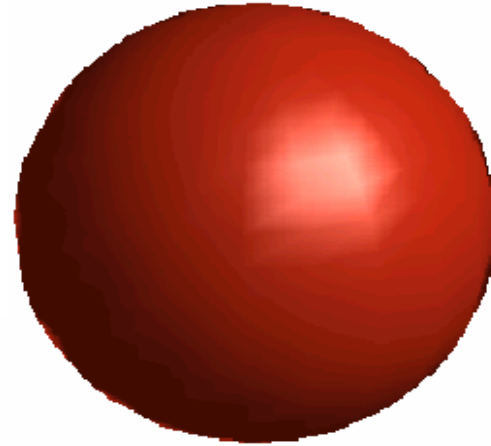


# Polygon Rendering Methods

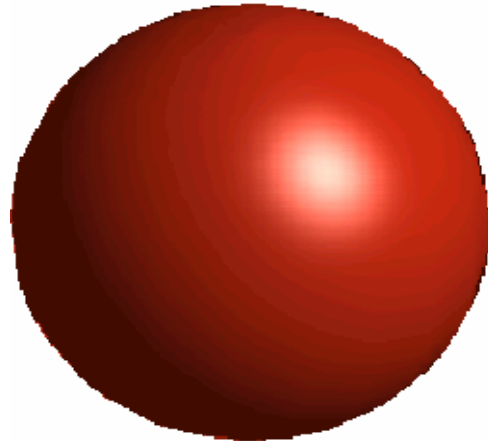
- **Example:**



Flat



Gouraud



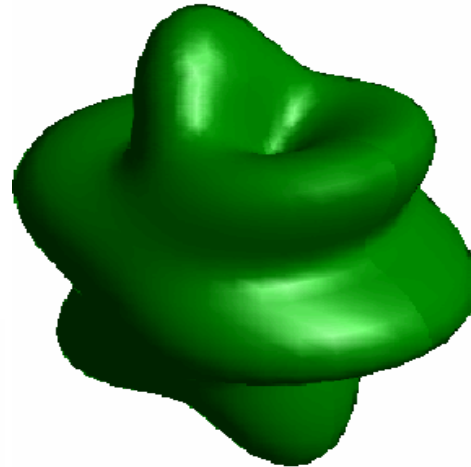
Phong

# Polygon Rendering Methods

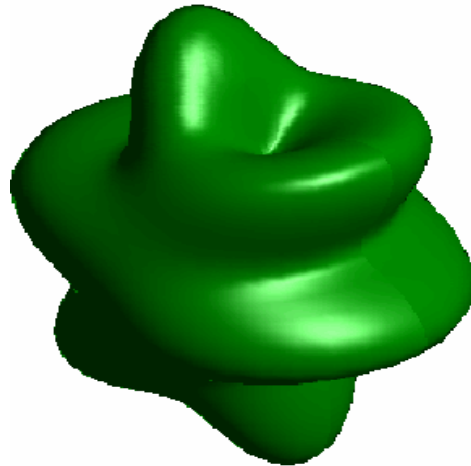
- **Example:**



Flat



Gouraud



Phong

# Polygon Rendering Methods

- **Example:**



Flat



Gouraud



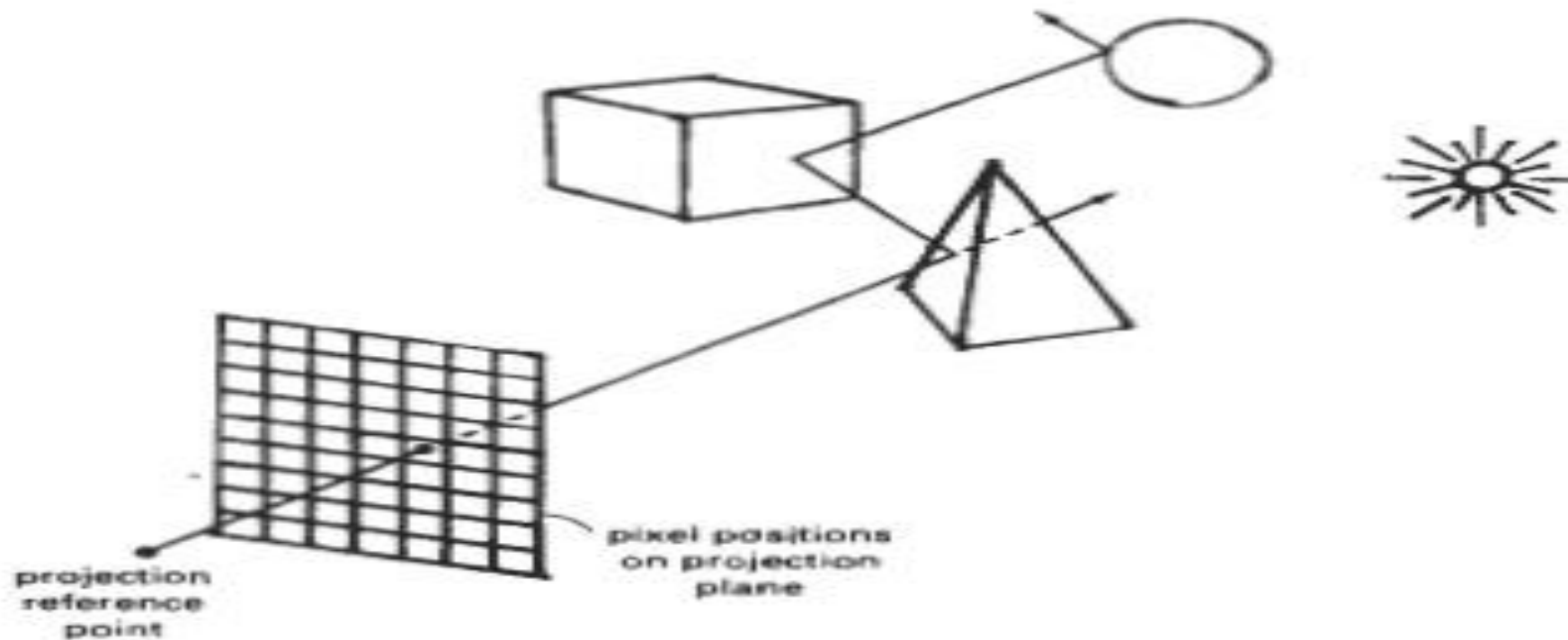
Phong



# Ray Tracing Methods

- In case of ray tracing, instead of looking for the visible surface for each pixel, we continue to bounce the ray around the scene, collecting intensity distribution.
- It is simple and powerful rendering technique for obtaining global reflection and transmission effects
- The basic ray tracing algorithm provides for visible surface detection, shadow effects, transparency and multiple light source illumination.
- Advantage: ray traced displays can be highly realistic particularly for shining objects.
- Disadvantage: Requires considerable computation time to generate.

# Ray Tracing Methods



*Figure 14-49*

Tracing a ray from the projection reference point through a pixel position with multiple reflections and transmissions.

# Anti Aliased Ray Tracing

- Displayed primitives generated by raster algorithm have a jagged appearance because the sampling process digitizes coordinate points on an object to discrete integer pixel positions.
- This distortion of information due to low frequency sampling is called aliasing.
- But this appearance can be improved by applying antialiasing methods.

